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The effect of seated and supine exercise on executive function in TIA patients and healthy controls.

A thesis presented in fulfilment of the requirements for the degree of Master of Health Science in Sport and Exercise at Massey University, Wellington.

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"I certify that all material in this dissertation which is not my own work has been identified and that no material is included for which a degree has previously been conferred upon me."

Signed:

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List of Abbreviations

ANOVA - Analysis of variance

AT - Aerobic training group

BDNF - Brain-derived neurotrophic factor

BF % - Body fat percentage

BG - Blood glucose

BMI - Body mass index

BOLD - Blood-oxygen-level dependent

CI - Confidence intervals

DBP - Diastolic blood pressure

DPF - Differential pathlength factor

DSBT - Digital span backwards test

DV - Dependent variable

ECG - Electrocardiogram

EEG - Electroencephalography

FIM - Functional independence measure

fMRI - Functional magnetic resonance imaging

GET - Gaseous exchange threshold

GXT - Graded exercise test

HC - Healthy controls

HDL - High-density lipoprotein

HHb - Deoxy-haemoglobin

HR – Heart rate

HRR - Heart rate reserve

HR_{Max} - Maximum heart rate

HSD - Honest significant difference

IV - Independent variable

LDL - Low-density lipoprotein

MoCA - Montreal cognitive assessment

NIHSS - National Institutes of Health Stroke Scale

NIRS - Near infrared spectroscopy

O_2Hb - Oxy-haemoglobin

PASAT - Paced auditory serial addition test

PET - Positron-emission tomography

PO - Power output

RAVLT - Rey auditory verbal learning test

RER - Respiratory exchange ratio

RHR - Resting heart rate

RM - Repetition maximum

RPE - Ratings of perceived exertion

RPM - Revolutions per minute

RT - Resistance training group

SBP - Systolic blood pressure

SDST - Symbol digit substitution test

SIS - Stroke impact scale

SNR - Signal-to-noise ratio

SPECT - Single-photon-emission computed tomography

SRTT - Serial reaction timed task

TC - Total cholesterol

THb - Total haemoglobin

TIA - Transient ischemic attack

TSI - Tissue saturation index

$\dot{V}CO_2$ - Carbon dioxide

$\dot{V}_E$ - Minute ventilation

$\dot{V}O_2$ - Oxygen consumption

$\dot{V}O_{2Max}$ - Maximal oxygen consumption

$\dot{V}O_{2peak}$ - Peak oxygen consumption

WCST - Wisconsin card sorting task

WWT - Walking while talking test

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Abstract

Purpose: Exercise is suggested to improve executive function in healthy adults. However, there is limited research in this area on stroke populations. The purpose of this study was to examine the effects of an acute sub-maximal bout of seated and supine exercise on executive function in transient ischemic attack (TIA; minor stroke) patients and an age-matched healthy control group (HC). **Methods:** Nine TIA patients (7 males, 2 females; 65.1 ± 10.1 y; 85.8 ± 16.9 kg) and fifteen HC participants (13 males, 2 females; 61.5 ± 7.1 y; 84.9 ± 16.3 kg) performed two familiarisation sessions and four laboratory-based exercise protocols on a cycle ergometer. During the laboratory-based exercise tests participants performed two continuous, incremental maximal graded-exercise tests (GXT) to volitional exhaustion; one test was performed on a seated cycle ergometer, the other on a cycle ergometer in a supine position. The two remaining tests were 30-minute sub-maximal exercise tests (Seated and Supine). The Stroop task assessed executive function and was performed prior-to (Baseline), immediately after (Post) and 15-minutes (15-min Post) following the sub-maximal exercise tests. Near infrared spectroscopy (NIRS) was continuously recorded throughout the entire testing protocol to assess changes in total haemoglobin (tHb), oxy-haemoglobin (O_2Hb), deoxy-haemoglobin (HHb), and tissue saturation index (TSI). **Results:** Regardless of exercise modality (Seated cf. Supine) or condition (TIA cf. HC) ($P < 0.05$), exercise elicited significant improvements in the time to complete the Stroop task (Baseline: 61.3 ± 10.0 s; Post: 58.1 ± 9.4 s; 15-min Post 54.8 ± 9.0 s). There were no changes in the number of correct Stroop answers reported for Seated exercise across each assessment time point ($P > 0.05$). However, a significant decrease in the number of correct answers was revealed immediately after (Post) Supine exercise which increased 15-minutes after exercise ($P < 0.05$). There was a significant increase in tHb (-0.6 ± 7.3 cf. 15.6 ± 8.1 %) and O_2Hb (-2.3 ± 10.9 cf. 22.2 ± 11.1 %) after exercise (Baseline to Post) which remained significantly higher 15-minutes following exercise regardless of the exercise modality (Seated cf. Supine) or condition (TIA cf. HC) (both $P < 0.001$). **Conclusion:** This study showed 30-minutes of sub-maximal exercise in a seated and supine position led to improvements in executive function in TIA and HC participants. Cognitive improvements were observed immediately and 15-minutes after exercise. Possible mediators include increases in cerebral oxygenation and neurotransmitters. These findings may be important for improving executive function, a cognitive domain greatly impaired by stroke. Future research should further investigate the underlying mechanisms by which exercise affects executive function in stroke patients.

1. Introduction

In New Zealand, stroke is the third leading cause of death and a significant cause of serious adult disability with more than two thirds of stroke patients dependent on others for care (Ministry of Health, 2013; Heart and Stroke Foundation, 2012; Gommans, et al., 2009; Hillary Commission, 2008). As a consequence of stroke, the majority of survivors are disabled and need constant support in their activities of daily living (Stroke Foundation, 2014; Heart and Stroke Foundation, 2012; Ministry of Health, 2009). Exercise has been shown to enhance numerous physiological and psychological impairments of stroke that may restrict a stroke patient's ability to perform their daily activities and affect their quality of life (Durstine, et al., 2009). This includes enhancing cardiovascular function and functional capacity and reducing stress, fatigue, anxiety and depressive feelings (Hackett, et al., 2009; Lai, et al., 2006; Gordon, et al., 2004). Cognitive function after a stroke may also be significantly impaired and it is estimated that over half of all stroke patients have various cognitive deficits (Marzolini, et al., 2012). Common cognitive impairments such as difficulty paying attention, planning, organising or recalling information further reduce a stroke patient's ability to live independently (Quaney, et al., 2009). In more recent years, research has begun to investigate methods to improve cognitive impairments of stroke by exploring the effects of exercise on cognitive function (Marzolini, et al., 2012; Kluding, et al., 2011; Ploughman, 2008).

The effects of exercise on cognitive function in stroke patients are not well understood and research is very limited (Marzolini, et al., 2012; Kluding, et al., 2011). Most studies are dominated by a focus on healthy adult populations and have shown that exercise generally has a positive effect on cognitive function and performance (Chang, et al., 2012; Marzolini, et al., 2012). Although there are various aspects of cognition such as information processing or memory, the cognitive domain that appears the most sensitive to the beneficial effects of exercise is executive function (Chang, et al., 2012; Best, 2010; Pesce, et al., 2009; Anderson, 2002). Executive function has a crucial role in human life because it involves cognitive, emotional and motor functioning that allows the ability to perform everyday life activities such as going to work or developing and maintaining appropriate social relations (Manders, 2012; Chan, et al., 2008). Evidence that has addressed the effects of aerobic exercise and executive function in healthy adults is promising as it may be applied to improving executive function in stroke patients which is

a cognitive domain frequently impaired after a stroke (Cumming, et al, 2012; Chang, et al., 2012; Ploughman, 2008; Sibley, et al., 2006; Nys, et al., 2005).

There are various physiological mechanisms that have the potential to explain the relationship between aerobic exercise and cognitive function improvements including increased brain-derived neurotrophic factor (BDNF) concentration (Huang, et al., 2014), increased neurotransmitters concentration (McMorris, et al., 2008) and increased cerebral blood flow (Marmeleira, 2013; Ploughman, 2008). Exercise may increase levels of BDNF in the brain and increase the arousal, secretion and metabolism of neurotransmitters such as dopamine and norepinephrine (Huang, et al., 2014). The increase in both these mechanisms (BDNF, neurotransmitters) may have a positive influence on cognitive function via enhanced synaptic transmission (Huang, et al., 2014; Nehring, 2012; Purves, et al., 2013). Increased cerebral blood flow is considered to mediate the effects of exercise on cognitive performance (Lucas, et al., 2012). Cerebral blood flow may increase up to 30 % during aerobic exercise which is associated with improved transport of oxygen and glucose to the brain and improved removal of biological waste products (Nehring, 2012; Lojovich, 2010). Elevated levels of cerebral blood flow and cerebral oxygenation may also relate to improved cognitive function particularly for executive function tasks (Seifert & Secher, 2011; Hiura, et al., 2010). The increase in blood flow to the brain suggests increased neuronal activity which may facilitate improvements to cognitive performance (Lucas, et al., 2012; Ide & Secher, 2000). Although exercise is suggested to benefit cognitive function, interpretations of the mechanisms that underlie this relationship in stroke patients are difficult because studies differ extensively in the methodologies (Chang, et al., 2012).

Most studies on stroke patients focus on chronic exercise interventions compared to acute exercise with different exercise durations and intensities (Quaney, et al., 2009; Ploughman, et al., 2008). Thus, it is challenging to infer optimal conditions for exercise to benefit cognitive performance in stroke patients (Chang, et al., 2012; Marzolini, et al., 2012; Ploughman, et al., 2008). Research has also used various exercise modalities which generally involve exercises such as cycling or walking (Marzolini, et al., 2012; Rand, et al., 2010). However, as most research has focused on healthy adults, some exercise modes may not be suitable for stroke patients (Durstine, et al., 2009). Imbalance may be a problem for many stroke patients and trying to maintain their balance on a cycle ergometer or treadmill may be difficult and unsafe (Gordon, et al., 2004). Supine or recumbent positions may be recommended to enhance safety (Pesce, et al., 2009; Gordon, et al.,

2004). Conversely, cognitive functions may be affected by physiological changes that occur when postural position is manipulated during different exercise modes (Ozgoren, et al., 2012; Kato, et al., 2011). Accordingly, the present study examines the effects of an acute sub-maximal bout of moderate intensity exercise in a seated and supine position on executive function in TIA patients and healthy older adults. The immediate and delayed effects on cerebral oxygenation measured with NIRS will be assessed up to 15-minutes following exercise. Investigation of this relationship may be important in regard to practical applications concerning improvements to cognitive impairments after a stroke.

2. Literature Review

2.1 Epidemiology of stroke

Stroke is a major cause of disability and death worldwide and is the third leading cause of death in New Zealand (Stroke Foundation, 2014; Ministry of Health, 2009). Each year around 9000 New Zealanders will have a stroke and it is estimated that there are currently 60,000 stroke survivors in New Zealand (Stroke Foundation, 2014). Nearly three quarters of this stroke population are disabled, need constant support in their activities of daily living and are dependent on others for care (Stroke Foundation, 2014; Heart and Stroke Foundation, 2012; Ministry of Health, 2009). Approximately one-third of these patients will have another stroke within five years (National Stroke Association, 2013; Lawrence, et al., 2011). At least 80 % of strokes are considered preventable, it is important to determine optimal treatment, prevention and rehabilitation strategies to reduce the risk, morbidity and mortality rates of stroke (World Health Organisation, 2014).

2.2 Risk factors for stroke

Non-modifiable risk factors cannot be changed as they identify a person who may have an increased risk of stroke and include race, gender, family history and age (Stroke Foundation, 2014; Go, et al., 2013; Goldstein, et al., 2011). For example, the risk of stroke doubles each decade of life after the age of 55 years (American Stroke Association, 2012; Goldstein, et al., 2011). Although strokes can affect people of all ages, 75 % of strokes occur in people over 65 years (Stroke Foundation, 2014). Modifiable risk factors of stroke can be amended and include hypertension (systolic blood pressure $\geq$ 140 mmHg; diastolic blood pressure $\geq$ 90 mmHg), physical inactivity, tobacco smoking, excessive alcohol intake, high waist to hip ratio, psychosocial stress and depression, dyslipidaemia, unhealthy diet, diabetes mellitus and cardiac pathologies (e.g. coronary artery disease, atrial fibrillation) (Marzolini, et al., 2012; Goldstein, et al., 2011; O'Donnell, et al., 2010; Patel & Punekar, 2010). Previous research findings have suggested that the ten aforementioned risk factors are associated with 90 % of the risk of stroke (O'Donnell, et al., 2010). However, hypertension alone is considered the single most important risk factor for stroke (World Heart Federation, 2013). It is reported that approximately 80 % of people who have strokes also have hypertension (Lloyd-Jones, et al., 2010). Literature suggests that a person with hypertension is seven times more likely than a person with

normal blood pressure (systolic blood pressure ≤ 120 mmHg; diastolic blood pressure ≤ 80 mmHg) to have a stroke (Stroke Foundation, 2014; American Medical Association, 1998).

2.3 Pathophysiology of stroke

A stroke is when blood flow to a region of the brain is obstructed causing a rapid loss in cerebral function (Durstine, et al., 2009). Stroke affects cerebral function for more than 24 hours or until death, with no apparent cause other than that of vascular origin (American Heart Association, 2012). During this period, the brain is deprived of oxygen and nutrients which can lead to brain cell or tissue damage and death (Gorelick, 2002). Stroke can be differentiated in two major categories; haemorrhagic and ischemic strokes (see Figure 1; National Stroke Association, 2013; American Stroke Association, 2012).

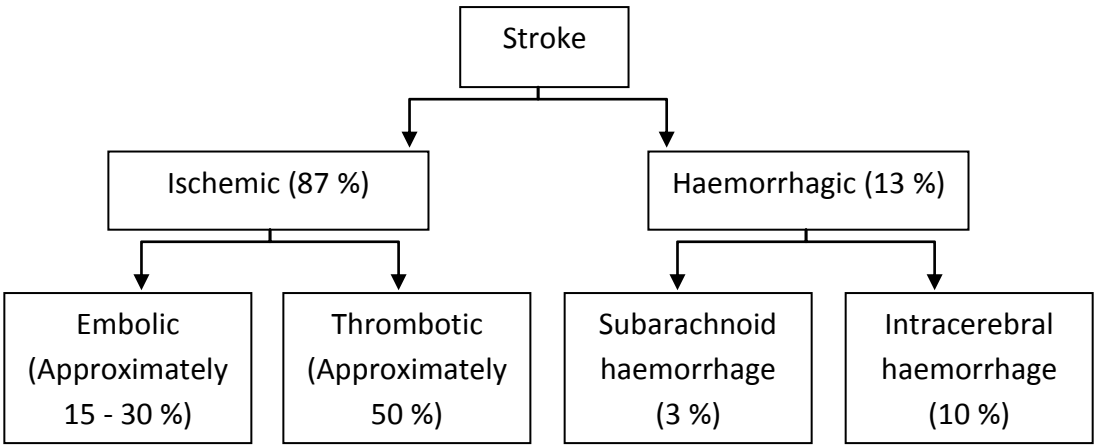


Figure 1. Summary of the different classifications of stroke.

Source: Adapted from American Heart Association. (2012). Heart Disease and Stroke Statistics – 2012 Update. *Circulation, 125,* E2-E220.

It is estimated that 13 % of stroke cases are from haemorrhagic stroke, which are responsible for more than 30 % of all stroke deaths (National Stroke Association, 2013). A haemorrhagic stroke occurs when weakened blood vessels, often caused by hypertension, rupture or leak in areas of the brain (Appel & Linas, 2012). The bleeding accumulates and compresses the surrounding brain tissue depriving brain cells of blood flow and causing cell or tissue damage and death (Zorowitz, et al., 2004). An ischemic stroke occurs when there is a deficiency in oxygen to the brain due to an obstruction within a blood vessel that supplies blood flow to the brain (Abou-Chebl, 2013). Ischemic strokes are the most common kind of stroke causing 87 % of all strokes (Durstine, et al., 2009). The underlying cause of ischemic stroke is considered to be atherosclerosis (National Stroke Association,

2013; American Stroke Association, 2012). Atherosclerosis is a condition where the arteries harden and narrow as a result of excessive formation of atheromatous plaques which disrupts blood flow (Durstine, et al., 2009). The atherosclerotic process is initiated from slight damage or injury to the endothelium, the inner lining of an artery which can be a consequence of the risk factors for stroke (see section 2.2; Abou-Chebl, 2013; Appel & Linas, 2012; Pepine, 1998). An ischemic stroke is further classified as an embolic or thrombotic stroke which reflects how the blood vessels within the brain have become obstructed (National Stroke Association, 2013). An embolic stroke involves a blood clot (embolus) formed in another location in the circulatory system, usually the heart, which travels to and blocks blood vessels within the brain (Iadecola & Gorelick, 2004). A thrombotic stroke refers to a blood clot (thrombus) which has developed on deposits on blood vessels within the brain and impairs blood flow causing the loss of brain cell function (Iadecola & Gorelick, 2004). Thrombosis is the process that leads up to the blockage and is responsible for nearly half of all stroke cases (Stroke Foundation, 2014).

Typical signs and symptoms of an ischemic stroke last longer than 24 hours and may include hemiparesis (partial weakness or paralysis) or hemiplegia (total paralysis) to one side of the body, cerebral ataxia (co-ordination and gait difficulties), aphasia (language and speech difficulties), confusion, visual disturbances (hemianopia - vision loss or blindness in one or both eyes) and vertigo (dizziness, disorientation, lack of balance) (Kerber, et al., 2006; Zhang, et al., 2006; Flansbjer, et al., 2005; Pedersen, et al., 2004). Cognitive impairments after a stroke are a major cause of disability which limits a stroke patient's ability to live independently (Stroke Foundation, 2014). Common cognitive deficits relate to disturbances of attention, confusion, memory problems and planning, interpreting and executing complex tasks and information (Rand, et al., 2010).

2.3.1 Transient ischemic attack (TIA).

A TIA has the same signs and symptoms as an ischemic stroke (National Institutes of Health, 2014). However, the symptoms of a TIA resolve within 24 hours with the majority of symptoms only lasting 30- to 60-minutes (Gommans, et al., 2009; Johnston, et al., 2000). A TIA is often referred to as a "mini stroke" which involves the temporary disruption of blood flow to the brain causing an acute loss of focal, cerebral or ocular function (Durstine, et al., 2009). Similar to an ischemic stroke, a TIA occurs when a blood clot obstructs blood flow to an area within the brain (Lawrence, et al., 2011). Inadequate

cerebral blood supply (from thrombosis or embolism) and weakened and narrowed arteries within the brain (from atherosclerotic processes) are considered to lead to the temporary blockages of a TIA (Intercollegiate Stroke Working Party, 2004; Hankey & Warlow, 1994). Therefore, a TIA is perceived as a warning sign for impending stroke and approximately 15 % of all strokes are thought to be preceded by a TIA (National Stroke Association, 2013; Gommans, et al., 2009; Hankey, 1996).

Although a TIA resolves rapidly and does not usually cause permanent injury to the brain, urgent treatment procedures should be engaged as there is the risk of recurrent stroke (Gommans, et al., 2009). Meta-analyses have demonstrated that there is a short-term risk of stroke after a TIA that is between 3 to 10 % after two days and 9 to 17 % after 90 days (Go, et al., 2013; Giles & Rothwell, 2007; Wu, et al., 2007). It is also estimated that within one year of a TIA, 12 % of patients will die (Kleindorfer, et al., 2005). This supports the importance of interventions and preventative measures that have the potential to reduce the risk of disability and death from recurrent stroke. Current stroke treatments involve several types of prescribed medicines such as anti-coagulants and anti-platelets and other medication that lowers blood pressure and cholesterol levels (Heart and Stroke Foundation, 2012). However, it is important to address behavioural and lifestyle modifications regarding the risk factors for stroke (see section 2.2; Gommans, et al., 2009). Recommended interventions to prevent secondary stroke predominantly target lifestyle risk factors associated with alcohol and tobacco intake, diet and physical activity (National Stroke Foundation, 2012; Lawrence, et al., 2012; Gommans, et al, 2009).

2.4 Exercise and stroke

Exercise and physical activity have an increasing evidence base in the primary and secondary prevention of stroke and in stroke rehabilitation (Gallanagh, et al., 2011; Beaglehole & Bonita, 2009). Regular exercise after a stroke is suggested to reduce mortality by more than 20 % and improve functional capacity (Durstine, et al. 2010). Several psychological (see section 2.4.1) and physiological benefits (see section 2.4.2) of exercise have recently become established for promoting health and reducing risk factors for individuals living with the effects of stroke (Billinger, et al., 2014; Globas, et al., 2012; Gordon, et al., 2004).

2.4.1 Psychological benefits of exercise for stroke patients.

Research has illustrated a range of psychological benefits of exercise for stroke patients (Dishman & O'Connor, 2009; Hackett, et al., 2009; Gordon, et al., 2004). Exercise is suggested to boost self-esteem and reduce stress, fatigue, anxiety and depressive feelings as exercise stimulates the release of endorphins and acts an analgesic by reducing perceptions of pain (Dishman & O'Connor, 2009; Mead, et al., 2009). There are several studies which support exercise reducing the risk of depression in stroke patients which may be associated to increased endorphins which arouse positive euphoric feelings (Hackett, et al., 2009; Lai, et al., 2006; Gordon, et al., 2004; Rimmer, et al., 2000). Another psychological benefit of exercise relates to the quality of life for stroke patients. Exercise has been shown to increase mobility and physical independence in stroke patients which improves their performance for activities of daily living thus enhancing their overall quality of life (Billinger, et al., 2014; Altieri, et al., 2012).

2.4.2 Physiological benefits of exercise for stroke patients.

The physiological benefits of exercise for stroke patients primarily relate to a decrease in risk factors associated with stroke and cardiovascular disease and improvements to their cardiovascular fitness and functional capacity (Billinger, et al., 2014; Gordon, et al., 2004). As previously mentioned, there is a well-recognised relationship between hypertension and stroke. Emerging research has suggested that exercise is associated with an average 5 to 8 mmHg reduction in systolic and diastolic blood pressure in healthy and hypertensive patients (Gallanagh, et al., 2011; Lambert, 2011). Therefore, exercise has been suggested to positively alter a major contributor to stroke risk (hypertension) which may reduce the risk of recurrent stroke by 30 to 40 % (Gallanagh, et al., 2011; Lambert, 2011; Durstine, et al., 2009; Dickinson, et al., 2006; Bacon, et al., 2004). Other physiological benefits of aerobic exercise relating to cardiovascular fitness include hypertrophy of cardiac muscles and increased blood and stroke volume which improve coronary blood supply and decreases resting heart rate (Globas, et al., 2012; Goldstein, et al., 2011; Durstine, et al., 2009).

There is also evidence that exercise improves functional capacity in stroke patients (Billinger, et al., 2014; Durstine, et al., 2009; Gordon, et al., 2004). Aerobic exercise interventions in stroke patients have evoked significant improvements to: peak oxygen consumption and workload; blood pressure response during sub-maximal exercise;

exercise duration, velocity and endurance; and sensorimotor function (Billinger, et al., 2014; Durstine, et al., 2009; Gordon, et al., 2004). Furthermore, the latter was significantly related to improvements in aerobic capacity (Gordon, et al., 2004; Potempa, et al., 1995). This is beneficial for stroke patients as aerobic capacity is often compromised after a stroke and is reported to be as low as 50 to 70 % of age and sex-matched sedentary controls (Pang, et al., 2006; MacKay-Lyons & Makrides, 2004). It is suggested this is from low initial fitness and sedentary behaviour after a stroke (Gordon, et al., 2004; MacKay-Lyons & Makrides, 2004).

Positive changes from chronic aerobic exercise include enhanced glucose regulation; decreased insulin resistance; increased high-density lipoprotein (HDL) cholesterol; reduced LDL (low-density lipoprotein) cholesterol and triglycerides; and reduced total body fat, which may help to prevent obesity, dyslipidaemia, and the development of Type 2 diabetes, all of which can contribute to the risk of stroke (Gallanagh, et al., 2011; Lakka & Laaksonen, 2007; Sanossian & Ovbiagele, 2006). Additionally, the benefits of resistance exercise include improvements to muscle strength, gait, co-ordination and balance which can enhance stroke patients physical independence, mobility and ability to perform activities of daily living (Go, et al., 2013; Gordon, et al., 2004). Furthermore, aerobic and resistance exercise may promote improvements in daily activities that require fine motor skills such as tying shoe laces or writing as motor function is often impaired after stroke (Mang, et al, 2013).

Aerobic and resistance exercises have increasingly become recognised as important components of stroke recovery and the prevention of secondary complications related to recurrent stroke and other cardiovascular diseases (Billinger, et al., 2014; Gallanagh, et al., 2011; Gordon, et al., 2004). However, exercise training for stroke patients remains under investigation. For example, the time to commence exercise after stroke remains controversial (Brethour, et al., 2012). Although it is considered that exercise should begin as early as possible after a stroke, there is yet to be specific protocols prescribed relating to the frequency, duration, intensity or exercise modality for the early stages of stroke recovery (Billinger, et al., 2014; Brethour, et al., 2012). For example, exercise interventions on cardiovascular fitness and stroke risk reduction reported that 30-minutes of moderate-intensity aerobic exercise was more effective than 60-minutes of lower-intensity aerobic exercise in reducing blood pressure and blood lipid levels (Gallanagh, et al, 2011; Rimmer, et al., 2009). The optimal exercise prescription for stroke patients is yet to be defined and the range of all possible benefits of exercise is not

fully explored (Billinger, et al., 2014). In addition to the physiological and psychological benefits of exercise, emerging literature suggests that exercise may also improve brain and cognitive function in stroke patients (Marzolini, et al., 2011; Rand, et al., 2010; Quaney, et al., 2009; Ploughman, et al., 2008).

2.5 Exercise and cognition

2.5.1 Acute exercise and cognition in healthy adults.

Cognition refers to the mental processes that acquire knowledge and understanding through thought, experience and the senses (Weiten, 2010). Cognitive function can be divided into different domains of ability such as attention, decision making, problem solving, language, perception, memory and executive function (Fiske & Taylor, 2013; Tyler, 2013). There is substantial evidence that suggests an acute bout of exercise can enhance cognitive function in both young and older healthy adults (Hogan, et al., 2013; Barella, et al., 2010; Chang, et al., 2012; Tomporowski, 2003; Brisswalter, et al., 2002). However, few studies have examined this relationship in stroke patients (see section 2.5.3; Ploughman, et al., 2008). Research has examined age differences in cognitive performance immediately following a single 15-minute bout of moderate intensity cycling (Hogan, et al., 2013). The cognitive improvements in this study demonstrated faster reaction times on cognitive tasks across all ages. These findings suggested exercise has important benefits for cognitive performance regardless of age (Hogan, et al., 2013).

Another study on healthy older adults had similar findings and showed a single 20-minute bout of moderate intensity treadmill exercise was beneficial for speed processing (Barella, et al., 2010). Furthermore, this study showed the cognitive improvements were maintained up to 120-minutes after exercise. Research supports improvements in cognitive performance with sub-maximal exercise up to 60-minutes duration (Tomporowski, 2003). However, it was noted that after this exercise duration information processing and memory functions can be compromised (Tomporowski, 2003). Studies regarding acute exercise need to be further explored as there remains controversy around the effects on cognitive function (Blanton, et al., 2012). Although the aforementioned studies have illustrated improvements in cognitive function, there is other research suggesting exercise can decrease, or not effect cognition function (Del Giorno, et al., 2010; McMorris, et al., 2009). However, this may be dependent on several moderating factors (see section 2.6)

such as the domain of cognition being assessed such as executive function (Chang, et al., 2012).

2.5.2 Cognition and executive function.

Executive function is considered to be one of the most important domains of cognition (Dewey & Prince, 2006). Executive function is suggested to be an umbrella term used for a hypothesised set of cognitive processes including working memory, inhibition, emotional control, initiation planning and organisation, self-monitoring and self-regulation and attention (for descriptions see Appendix A; Goldstein, et al., 2013; Diamond, 2012; Purdy, 2011). There is a general agreement that executive function relates to the management, regulation and control of these cognitive processes that serve to select, organise, remember and properly initiate goal-directed behaviours (Weiten, 2010; Meltzer, 2007; Alvarez & Emory, 2006). It is generally agreed that the frontal lobes, specifically the prefrontal cortex, play a critical role and largely contribute to the processes of executive function (Plotnik, 2013; Purves, et al., 2013). The cognitive domains that are most commonly affected by stroke are not entirely clear. However, there is consensus that executive function is a cognitive domain frequently impaired among stroke patients (Swatridge, 2014; Cumming, et al., 2012; Nys, et al., 2005). This is supported by the cognitive impairments observed in stroke patients that attribute to executive function such as difficulty paying attention, executing tasks, recalling or analysing information and difficulty planning and organising (Rand, et al., 2010).

2.5.3 Exercise and cognition in stroke patients.

Cognitive impairment is a well-established consequence of stroke that contributes to long term disability (Go, et al., 2013; National Stroke Association, 2013; Hankey, 1996). However, research studying the effects of aerobic exercise on cognitive function after a stroke has only emerged in recent years (Marzolini, et al., 2012). In addition to previously mentioned impairments of stroke (see section 2.3), research has shown that among 64 % of stroke patients suffer from cognitive deficits (Marzolini, et al., 2012; Kelly-Hayes, et al., 2003). Furthermore, cognitive impairment from stroke has been associated with a three-fold increase in mortality risk, increased rates of institutionalisation and decreased ability to perform activities of daily living (Marzolini, et al., 2012; Hobson & Meara, 2010; Pasquini, et al., 2007). However, there are currently very few studies that focus on this area in stroke recovery which supports reasons to

further explore the literature that examines the relationship between exercise and cognitive function in stroke patients (see Table 1).

Research explored 20-minutes of aerobic treadmill exercise at 70 % HRR and the impact on cognition and hemiplegic hand function in stoke patients (Ploughman, et al., 2008). The cognitive assessments used (Trail-making tasks, SDST, PASAT) measured cognitive domains relating to executive function, attention and processing speed (Chang, et al., 2012; Manchester, et al., 2004; McMorris, et al., 2003). Although cognitive improvements were observed in most tasks, this study was unable to ascertain whether aerobic was the definitive factor for the observed improvements (Ploughman, et al., 2008). It was suggested that these findings may have been a result of the learned response or that the exercise intensity and duration were not suitable in order to elicit cognitive benefits (Swatridge, 2014; Nehring, 2012; Ploughman, et al., 2008).

Research investigating exercise interventions over a longer time period examined the effects of an eight week moderate intensity (70 %HR_{MAX}) aerobic exercise programme in stroke survivors (Quaney, et al., 2009). The study compared an aerobic exercise group to a stretching group (Quaney, et al., 2009). Findings from this research showed significant improvements to cognitive functions including improved information processing speed in the aerobic exercise group. Although this study used several cognitive tests (SRTT, WCST, Stroop task, Trail-making task), the cognitive improvements after the exercise intervention were only significant in the SRTT and not specifically illustrated in executive function (Nehring, 2012). It was suggested that reasons for this relate to the study's small sample size or that the cognitive tasks were not sensitive enough to detect changes in cognitive function (Swatridge, 2014; Quaney, et al., 2009).

Table 1. Summary of findings from studies on the effects of exercise on cognition in stroke patients.

Publications	Participants	Intensity	Duration	Mode	Cognitive Task	Time Cognitive Task Administered	Main Findings
Marzolini et al., (2012)	**n:** 41 Stroke patients Age: 27 - 88 y **Time after stroke:** ≥10 weeks	40 % to 70 % HRR for AT 50 – 60 % 1-RM	90-min exercise class 1 day/week for 6 months.	AT: Walking, recumbent or upright cycling. RT: Free weights.	MoCA	Before and after intervention.	- Overall improvement on MoCA. - Improvements to attention/concentration. - Improvements to visuospatial /executive function.
Kluding, et al., (2011)	**n:** 9 Stroke patients **Age:** 45 - 76 y **Time after stroke:** 12 m to 118 m	50 % $\dot{V}O_{2Max}$ Moderate	20-min session 3 days/week for 12 weeks.	Aerobic exercise on recumbent stepper.	DSBT and Flanker test.	Before and after intervention.	- Significant relationship between aerobic fitness and improvement on the Flanker task. - Improvement on DSBT.
Rand, et al., (2010)	**n:** 11 Stroke patients with lower extremity hemiparesis. **Age:** 50 - 85 y **Time after stroke:** ≥ 12 m	RPE 13 Moderate	60-min session 2 days/week and one 60-min leisure session per week for 6 months.	Aerobic and recreational. Stretching, balance, and task-specific exercises.	DSBT, Digit symbol test, Trail-making task, WWT, the Stroop task and RAVLT	Before intervention, 3-months during intervention and after invention.	- 10 % improvements after 3 months for WWT. - 7 % improvements after 6 months for Stroop task and DSBT. - Exercise and recreation may improve executive function and memory.
Quaney, et al., (2009)	**n:** 38 Stroke patients **Age:** 44 -77 y **Time after stroke:** ≥ 6 m	70 % HR_{Max} Moderate & Light	45-min session 3 days/week for 8 weeks.	AEX: Cycling. SE: Stretching.	WCST, Stroop task, Trail-making task, SRTT	Before intervention, after intervention, and 2 months after intervention.	- Improved information processing speed in AEX group. - Improved SRTT in AEX group. - No difference between groups for WCST, Trail-making task or Stroop task.
Ploughman, et al., (2008)	**n:** 21 Stroke patients with hemiplegic hand function. **Age:** 32-78 y **Time after stroke:** 6 m to 60 m	70 % HRR or RPE 13 Moderate	20-min session.	Aerobic exercise: treadmill walking.	Trail-making tasks, SDST and PASAT	Before and after exercise.	- Improvements on cognitive tasks due to learned effect not exercise. - No difference between control and treatment groups. - Intensity and/or duration not sensitive enough.

Publications	Participants	Intensity	Duration	Mode	Cognitive Task	Time Cognitive Task Administered	Main Cognitive Findings
Mead et al., (2007)	**n:** 66 Stroke patients Age: 60 – 80 y **Time after stroke:** > 5 m	RPE 13 to 16	60-min session 3 days/week for 12 weeks.	Endurance and resistance training (e.g., cycle ergometry, star climbing, weights, Sit-to-stand).	FIM-cog, memory, problem solving questions	Before intervention, after intervention, and 4 months after intervention.	- No significant differences or improvement in cognitive function for both the exercise and control group.
Studenski et al. (2005)	**n:** 100 Stroke patients **Age:** y **Time after stroke:** > 2 m	Not reported.	3 days/week for 36 sessions over 3 months.	Progressive exercise programme targeting (strength, balance, endurance and upper extremity function).	FIM-cog, 2 SIS domains (memory and thinking communication)	Before intervention, after intervention, and 6 months after intervention.	- Significant improvement to cognitive functions. - Exercise group had rapid improvement in aspects of physical, social, and role function compared to normal care post stroke.
Bateman et al., (2001)	**n:** 157 Patients with severe brain injury **Age:** 16 - 65 y **Time after incident:** >5 m	60 % to 80 % HR_{MAX} Maintain 50 RPM	30-min session 3 days/week for 12 weeks.	Aerobic exercise: cycle ergometry.	FIM-cog	Before intervention, after intervention, and 3 months after intervention.	- Cognitive function was not a primary measure. - There were no interactions in cognitive performance between the control group and exercise group at any assessment time point.
Nilsson et al., (2001)	**n:** 73 Stroke patients **Age:** 24 - 67 y **Time after stroke:** ≥ 3 w	Not reported.	30-min session 5 days/week for approx. 2 months.	Aerobic exercise: Treadmill walking.	FIM-cog	Before intervention, after intervention, and 10 months after intervention.	- Cognitive function was used to describe the participants rather than a primary measure. - There were no difference between the control group and exercise group at any assessment time point.

HRR = Heart rate reserve; AT = Aerobic training group; RM – Repetition maximum; RT = Resistance training group; MoCA = Montreal cognitive assessment; $\dot{V}O_{2Max}$ = Maximal oxygen consumption; SRTT = Serial reaction timed task; WCST = Wisconsin card sorting task; RPE = Ratings of perceived exertion; SDST = Symbol digit substitution test; PASAT = Paced auditory serial addition test; DSBT = Digital span backwards test; HR_{Max} = Maximum heart rate; WWT = Walking while talking test; RAVLT = Rey auditory verbal learning test; FIM = Functional independence measure cognitive subsections; SIS = Stroke impact scale; RPM = Revolutions per minute.

Research by Rand et al. (2010) had a smaller sample size (N =11) than both the abovementioned studies yet a larger intervention period (6 months). This study examined the effects of aerobic recreational and leisurely exercise on cognitive and motor function in stroke patients with lower extremity hemiparesis (Rand, et al., 2010). Executive function and memory were assessed half-way through the intervention (at 3 months) in addition to pre- and post-invention assessments. Significant cognitive improvements were observed on cognitive tasks (Stroop task, RAVLT, DSBT) after six months. However, significant improvements on the WWT Test were observed at three months with no further improvements from three to six months. Cognitive improvements from three to six months appeared to plateau while motor function continued to improve (Rand, et al., 2010). These findings may question the long term improvement of cognitive function from exercise.

Several studies that examine the physiological and functional effects of exercise in stroke patients also indirectly assessed aspects of cognitive functions (see Table 1; Mead, 2007; Bateman, et al., 2001; Nilsson, 2001). These studies showed no significant improvements or differences in cognitive function between exercising and control groups up to ten months post exercise intervention. However, these studies used the same cognitive assessment tool (FIM) and the purpose of the cognitive assessment was to describe their participants (Mead, 2007; Bateman, et al., 2001; Nilsson, 2001). Moreover, a study that used a different cognitive assessment tool in addition to the FIM demonstrated improvements to cognitive functions including memory and thinking communication (Studenski, et al., 2005). This was observed immediately and six months after the three month progressive aerobic and resistance exercise programme (Studenski, et al., 2005).

A 12-week exercise programme involved a primary assessment of cognitive function and a secondary assessment of aerobic fitness in stroke patients (Kluding, et al., 2011). The intervention involved aerobic exercise and lower extremity strength exercise on a recumbent stepper. There was a non-significant trend in cognitive improvement after the exercise intervention for most of the cognitive assessments. However, working memory significantly improved and there was a significant relationship between improved aerobic fitness and the magnitude of improvements towards accuracy on the Flanker incongruent test (Kluding, et al., 2011). Research findings suggest that the combination of aerobic and strength exercise interventions may improve executive function in stroke patients (Swatridge, 2014; Nehring, 2012; Kluding, et al., 2011).

One recent study has developed this concept and uses both aerobic and resistance exercise in a six month intervention in stroke patients (Marzolini, et al., 2012). This study incorporated walking, stationary recumbent and upright cycling as the aerobic exercise modes and the resistance exercises were task specific, involved muscle actions performed during daily activities and used free weights and patient's body weight for strength training (Marzolini, et al., 2012). Findings from this research showed significant improvements to cognitive functions including attention, concentration and visuospatial and executive functions (Marzolini, et al., 2012).

It should be noted that most of the mentioned studies in Table 1 recruited participants who experienced a stroke at least five months prior to commencing the study. However, the time frame for participant recruitment ranged from three weeks (Nilsson, 2001) to 118 months after having a stroke (Kluding, et al., 2011). There is currently a consensus that exercise should begin as soon as possible after a stroke including during hospital inpatient care (Billinger, et al., 2014; Brethour, et al., 2012; Mol & Baker, 1991). Therefore, these studies may have elicited greater improvements in cognitive function if they were implemented earlier and had a shorter time frame from the time of stroke to the time of exercise intervention commencement (Billinger, et al., 2014).

All but one of the research studies reviewed chronic exercise interventions which occurred over a time period ranging from two to six months duration that were implemented to effect cognitive function in stroke patients (Marzolini, et al., 2012; Kluding, et al., 2011; Rand, et al., 2010; Quaney, et al., 2009). Ploughman, et al. (2008) was the only study that assessed an acute bout of exercise on cognitive function in stroke patients. Although few studies examine the acute effects of aerobic exercise on cognitive function in stroke patients, evidence suggests a single bout of exercise can enhance cognitive function in young and healthy older adults (Chang, et al., 2010). However, several potential moderators have been identified to affect this relationship (see section 2.6).

2.6 Moderators of the effects of exercise on cognition

There are several suggested moderator variables relevant for the effects of acute exercise on cognitive function that include exercise intensity and duration, exercise mode, timing of the cognitive task administration and cognitive task type (Chang, et al., 2012; Lambourne & Tomporowski, 2010).

2.6.1 Exercise intensity.

Exercise intensity is a primary moderator identified to effect cognitive function in adults (Pesce, et al., 2009; McMorris & Hale, 2012; Lambourne & Tomporowski, 2010). It is suggested that moderate intensity exercise is most beneficial on cognitive performance for adult populations (Tomporowski, 2003). Research has shown that 10-minutes of moderate exercise intensity at 50 % peak oxygen consumption ($\dot{V}O_{2peak}$) caused significant improvement to cognitive performance, reflected by faster reaction times on the Stroop interference task (Yanagisawa, et al., 2010). Another study in adult males comparing 20-minutes of low (RPE: 11), moderate (RPE: 13), and high (RPE: 15) intensity cycling demonstrated that the moderate exercise intensity was most beneficial for improving reaction time and error rates in cognitive performance (Kamijo, et al., 2007).

Low intensity exercise has shown to be beneficial during exercise yet has is suggested to have negative effects on cognitive performance after exercise in healthy adults (Chang, et al, 2012). Contrary to this, high intensity exercise has no effects on cognitive performance immediately after exercise but produces significant positive effects when cognitive testing is delayed after exercise (Chang, et al, 2012). Additionally, studies have suggested high intensity exercise may have a lesser effect on improvements to cognitive function due to exercise induced elevated stress hormones (Blanton, et al., 2012; Reynolds & Nicolson, 2007). It has also been suggested that fatigue from high intensity exercise may be detrimental to cognitive performance (Brisswalter, et al., 2002; Reilly, 1997; Hogervorst, 1996). However, these findings remain controversial as other studies have found conflicting results (McMorris, et al., 2008; Winter, et al., 2007). Conversely, research suggests exercise has positive effects on cognition regardless of exercise intensity (Colcombe, et al., 2003). However, the time the cognitive task was administered after exercise for this study was not considered.

2.6.2 Exercise duration.

Research has shown that short exercise duration, less than 20-minutes, will not affect cognitive function whereas exercise longer than 20-minutes will elicit positive results towards cognitive performance in adults (Chang, et al., 2012). This is supported by findings by Brisswalter, et al. (2002) and Ploughman, et al. (2008) which both drew conclusions that more than 20-minutes of exercise is needed to have significant improvements to cognitive performance in adult and stroke populations. However,

exercise duration that exceeds 60-minutes has shown to cause fatigue, dehydration, and depleted energy stores in adults (Tomporowski, 2003). The effect of prolonged exercise can be detrimental to cognitive functioning and has been associated with reduced executive function and memory performance in adults (Tomporowski, 2003; Arcelin, et al., 1997).

2.6.3 Cognitive task type.

Evidence suggests that specific types of cognitive tasks are greater than others at detecting changes in cognitive performance after exercise (Chang, et al., 2012; Lambourne & Tomporowski, 2010). It is predicted that cognitive tasks can be stronger for different cognitive functions, especially executive function (Barenberg, 2012; Kluding, et al., 2011; Etnier, et al., 1997). Exercise has shown significant negative effects on cognitive tasks such as backward digit span and simple reaction time tasks while tasks on attention only show immediate improvements (Chang, et al., 2012; Tomporowski, 2003). Most cognitive tasks on executive function which include accuracy or error rate and reaction or response time display positive effects after exercise (Chang, et al., 2012). Examples of cognitive tasks that measure executive functions include verbal fluency tests, choice reaction time tasks and the Stroop task (Sibley, et al., 2006; Barella, et al., 2010). These are considered to be valid and reliable measures of executive function in which exercise has evidently had significant positive effects on cognitive performance immediately and after a delay following exercise (Chang, et al., 2012). Specifically, the Stroop task is well established as a reliable cognitive task with high test-rest reliability commonly used across all age groups to assess executive function with a focus on reaction times and information processing speed (Chang, et al., 2012; Penner, et al., 2012; Sibley, et al., 2006; Stroop, 1935). As these cognitive abilities are suggested to decline with age, the Stroop task is popular when evaluating various groups of patients with borderline or established brain pathology (Van der Elst, et al., 2006; Moering, et al., 2003).

2.6.4 Time cognitive task administered.

The timing of cognitive task administration is suggested to influence the effects of acute exercise on cognitive function (Chang, et al., 2012; Lambourne & Tomporowski, 2010). Negative effects on cognitive function were found immediately and after a delay following exercise when cognitive tests were administered between 0- and 10-minutes after exercise (Chang, et al., 2012). It is further suggested that cognitive tasks performed

11- to 20-minutes after exercise generally have the largest positive effects which then begin to subside after a 20-minute delay (Chang, et al., 2012). Although reasoning for this effect is unclear, it is hypothesised that physiological changes during exercise mediate potential mechanisms that underlie transitory benefits to cognitive performance (Barella, et al., 2010). A study in healthy older adults aged 60 to 90 years has shown an acute 25-minute exercise bout lead to improvements in cognitive tasks on executive function performed at 12 different time points after exercise (Barella, et al., 2010). Participants improved their time to complete several cognitive Stroop tasks immediately after exercise with improvements on cognitive performance peaking approximately 20-minute after exercise cessation. The improvements were maintained up to 60-minutes after exercise. Thereafter, the time to complete the Stroop task began to slow yet performance still remained significantly higher than baseline performance up to 120-minutes after exercise (Barella, et al., 2010).

2.6.5 Exercise mode.

Although the exercise mode may not primarily be a moderator of cognitive performance, the exercise mode should be carefully selected and adapted to the needs of stroke patients (Chang, et al., 2009). For example, treadmill running may be inappropriate for stroke patients with hemiplegia or paresis and special protocols have instead used arm or leg cycle ergometers in a seated position to optimise and ease the load (Gordon, et al., 2004; Fletcher, et al., 1994). Most experimental studies on the effect of exercise on cognitive function use aerobic exercises such as cycling, walking and running performed on a cycle ergometer or treadmill (Brisswalter, et al., 2002). Research has suggested that there are larger, positive effects on cognitive function after cycling exercise compared to running exercise (Hildt & Franke, 2013; Lambourne & Tomporowski, 2010). Although reasons for this remain unclear, it has been suggested that treadmill running requires considerably more balance and co-ordination which may be disruptive and reduce attention to the cognitive tasks performed during exercise (Ministry of Health, 2003).

Exercise modes that manipulate the body's postural position during exercise can cause physiological changes that may affect cognitive function (Ozgoren, et al., 2012; Kato, et al., 2011). It is suggested the 'gravitational assist' is reduced in a recumbent position and negated in a supine position as forces are evenly distributed throughout the body which in turn affects the dynamics of oxygen uptake (Masakazu, et al., 2005).

Conversely, research has shown no differences in oxygen consumption ($\dot{V}O_2$) kinetic responses between an upright and recumbent position (Egaña, et al., 2010). Research suggests muscle perfusion pressure is affected in different postural positions which limit and controls muscle $\dot{V}O_2$ kinetics (Jones & Poole, 2005). In addition, research has reported haemodynamic changes occur in different postural positions to cardiac output and cerebral blood flow during exercise which may be reduced in a supine position (Ozgoren, et al., 2012),

Exercise modes using seated cycle ergometry are associated with the ability to achieve a higher heart rate and greater $\dot{V}O_{2peak}$ compared to a recumbent position (Egaña, et al., 2010). However, in the recumbent position, the legs are raised in a horizontal position which helps blood flow return to the heart more efficiently, increases blood volume and lowers heart rate (Kato, et al., 2011; Walsh-Riddle & Blumenthal, 1999). The perceptual response may also be affected from this as it may feel easier for individuals to cycle (Masakazu, et al., 2005; Jones & Poole, 2005).

For many stroke patients, imbalance is a problem and trying to maintain their balance on a cycle ergometer may be difficult and unsafe (Gordon, et al., 2004). In these conditions, a supine or recumbent position may be recommended so the patient can perform their exercise safely (Durstine, et al., 2009; Gordon, et al., 2004). Nonetheless, it is reported that muscle fatigue and contractile performance are altered when an exercising limb is raised or lowered relative to the level of the heart (Fitzpatrick, et al., 1996). As a result, this has been associated with increased fatigue and reduced performance in exercise supine and recumbent positions (Egaña, et al., 2010).

2.7 Physiological links between exercise and cognition

There are several potential physiological mechanisms that may be responsible for the effect of exercise on cognitive function (Ando, et al., 2011; Tomporowski, 2003; Brisswalter, et al., 2002). The physiological changes to the central nervous system induced by exercise include metabolic, neuro-hormonal and circulatory effects relating to BDNF mechanisms, neurotransmitters and cerebral blood flow (Huang, et al., 2014; Barenberg, 2012; Ando, et al., 2011; Meeusen & De Meirleir, 1995).

A physiological explanation for the exercise induced effects on cognition can be mediated by the up regulation of growth factors such as BDNF (Huang, et al., 2014; Ferris, et al., 2007). Chronic exercise may increase levels of BDNF which appears to mediate neurogenesis and increase long-term potentiation (long-lasting enhancement in neuronal signal transmission) which is associated with improved cognitive function (Huang, et al., 2014; Ferris, et al., 2007; Churchill, et al., 2002). BDNF may also play an acute role in the enhancement of cognitive function via improved synaptic transmission after a single bout of aerobic exercise (Huang, et al., 2014; Schinder & Poo, 2000).

Exercise induced arousal of the central nervous system can increase levels and up-regulation of neurotransmitters including dopamine, glutamate, serotonin, norepinephrine and endorphins which may be responsible for the link between exercise and cognitive function (Barenberg, 2012; Best, 2010; Meeusen, et al., 2006; McMorris, et al., 2003; Meeusen & De Meirleir, 1995). Further research has shown increases in neurotransmitters after moderate intensity aerobic exercise remains elevated up to 120-minutes following exercise (Goekint, et al., 2012; Meeusen, et al., 1997). Additionally, the increased concentration of neurotransmitters from exercise is believed to improve cognitive function due to enhanced synaptic transmission (Swatridge, 2014; Meeusen & De Meirleir, 1995). However, most of this evidence primarily arises from animal models.

Another major physiological link between exercise and cognition relates to cerebral blood flow and oxygenation (Ando, et al., 2011). It is considered that brain function and tissue integrity are dependent on a continuous supply of oxygen because aerobic metabolism is the major energy source to the brain (Zauner, et al., 1997). Therefore, it is suggested that an increase in cerebral oxygenation and blood flow when the brain is activated during exercise, allows the brain to cope with the enhanced level of neuronal metabolism (Secher, et al., 2008). Studies in that support exercise increased cerebral blood flow has linked this effect to further increase in neural activity, oxygenation and total haemoglobin in the prefrontal cortex which has been associated with improved cognitive function (Endo, et al., 2013; Lucas, et al., 2012; Ekkekakis, 2009; Ide & Secher, 2000).

Chronic exercise is suggested to improve the age related decline in cerebral blood flow which improves cognitive function as a result (Lucas, et al., 2012; Rypma & D'Esposito, 2000). It is reported that cerebral blood flow may improve up to 30 % with aerobic exercise (Lojovich, 2010). This increase in cerebral blood flow leads to greater

oxygen and glucose transport to the brain and improved removal of biological waste products that can cause cerebral damage (Nehring, 2012; Lojovich, 2010). Exploring methods to increase cerebral blood flow is especially important in stroke patients with already compromised brain vessels as the increase in cerebral blood flow promotes angiogenesis, the formation of new blood vessels and improves blood flow to brain tissue (Nehring, 2012; Lojovich, 2010; Ploughman, et al., 2008). Research has shown an acute bout of moderate intensity exercise for 30-minutes increased global cerebral blood flow (Smith, et al., 2010). In contrast, another study in young adults found no significant changes in global cerebral blood flow with exercise (MacIntosh, et al., 2014). However, there was an increase in cerebral blood flow in the cerebral white matter 10- to 40-minutes after exercise (MacIntosh, et al., 2014). The inconsistencies between these findings suggest more research is required to understand the relationship between cerebral blood flow and exercise.

Cerebral blood flow has been suggested to increase during exercise (Perrey, 2008). However, the level to which cerebral oxygen saturation increases is mediated by the exercise intensity that tends to have a quadratic trend in incremental exercise (Rooks, et al., 2010). Between low and moderate exercise intensities, cerebral oxygenation steadily increases, but remains stable during moderate to hard intensities (Rooks, et al., 2010). During very hard, maximal or exhaustive intensities, cerebral oxygen levels begin to decline to similar values observed at low intensity exercise (Ide & Secher, 2000; Rooks, et al., 2010). Therefore, an increase in regional cerebral oxygen saturation during moderate intensity exercise suggests increased neuronal activation which in turn may relate to improved cognitive function (Ide & Secher, 2000; Villringer, et al., 1993).

During exercise, cerebral oxygenation is dependent on the cardiovascular and pulmonary systems to deliver an adequate oxygen supply to the brain (Ando, et al., 2011; Koike, et al., 2004). Therefore, the relationship between exercise and cognition may be mediated by cardio-respiratory fitness (Aichberger, et al., 2010). Furthermore, research suggests that cognitive function may be compromised when cerebral oxygenation decreases (Ando, et al., 2011). For example, strenuous exercise induced significant decreases in cerebral oxygenation in healthy adults who cycled at 80 % peak oxygen uptake which resulted in no improvements to their cognitive reaction time task (Ando, et al., 2011). Recently, research has further investigated the relationship between changes in cerebral perfusion and cognitive performance during exercise (Ekkekakis, 2009; Perrey, 2008). Cerebral perfusion is the net pressure gradient allowing cerebral blood flow to the

brain (Marieb & Hoehn, 2010). To date, there is minimal evidence to support acute increases in cerebral blood flow as a mechanism to directly link exercise and enhanced cognitive performance and further investigation is necessary (Lucas, et al., 2012). It is noted that most assessments of BDNF and neurotransmitters require invasive procedures whereas cerebral blood flow and oxygenation can be non-invasively assessed (Ekkekakis, 2009).

2.8 Assessment of cerebral blood flow

There are several instruments which can measure the haemodynamic changes in the cerebral cortex associated with cognitive function such as electroencephalography (EEG), single-photon-emission computed tomography (SPECT), positron-emission tomography (PET), Transcranial Doppler sonography, functional magnetic resonance imaging (fMRI), blood-oxygen-level dependent (BOLD) contrast imaging and near infrared spectroscopy (NIRS). A review by Ekkekakis, (2009) provides further information on these techniques. While fMRI is widely accepted as the gold standard for in vivo imaging of the human brain, NIRS has more recently become an increasingly popular technology to measure brain activity (Rooks, et al., 2010; Ekkekakis, 2009; Franceschini, et al., 2003). NIRS permits the investigation of oxygenation patterns in most biological tissues, including the cerebral cortex which is important when studying executive function (Ekkekakis, 2009). Examining oxygenation patterns may provide a useful insight towards mechanisms that underlie improvements to cognitive performance with exercise (Ando, et al., 2011). NIRS provides a method that is based on absorption changes in concentrations of the two main forms of haemoglobin, namely oxy-haemoglobin (O_2Hb) and deoxy-haemoglobin (HHb), in the tissue under investigation (Perrey, 2009; Ekkekakis, 2009). O_2Hb is oxygenated blood that serves to convey oxygen to tissues in order for metabolism to provide energy (Cui, et al., 2011). HHb is deoxygenated blood meaning it is not combined with oxygen and is formed when O_2Hb releases oxygen to the tissues (Bandettini & Wong, 2011). It is suggested there is an increase in O_2Hb to activated areas of the brain to compensate for the increase in metabolism (Bandettini & Wong, 2011). Additionally, the typical NIRS oxygenation response to an activated area in the cerebral cortex, involves a decrease in HHb accompanied by an increase in O_2Hb of a two to three-fold of magnitude (Perrey, 2009). O_2Hb is also suggested to be the most sensitive indicator that signifies increases in

cerebral blood flow (Perrey, 2008). The oxygenation and volume of the venous blood also determines the direction of changes in HHb (Perrey, 2009).

In addition to O_2Hb and HHb, NIRS may also monitor changes in derived parameters that are commonly reported as indices of oxygenation including tissue saturation index (TSI) and total haemoglobin (tHb) which can be used as an index of change in regional blood volume (Billaut, et al., 2010). During exercise, changes to O_2Hb, HHb and TSI are suggested to reflect the relationship between local oxygen delivery and utilisation (Rissanen, et al., 2012). Changes in tissue blood volume at the site of oxygen exchange can be detected with changes in tHb (Rissanen, et al., 2012; DeLorey, et al., 2003). NIRS has also been used to examine the possible quadratic response to incremental exercise of cerebral tissue oxygenation which increases from low to high intensities and then plateaus or begins to decline towards baseline values at very high or maximal intensities (Rissanen, et al., 2012; Rooks, et al., 2010).

NIRS has several advantages as it is considered a more convenient and less expensive technology in comparison to fMRI (Ekkekakis, 2009; Franceschini, et al., 2003). Although NIRS has been suggested to have significantly decreased and weaker signal-to-noise ratio (SNR), this technology is often highly correlated and compatible with fMRI measurements and BOLD-contrast imaging which is difficult to quantify (Cui, et al., 2011; Ekkekakis, 2009; Dunn, et al., 1999). Other benefits of NIRS include measurement of concentration changes in both oxygenated and deoxygenated haemoglobin, finer temporal resolution, and ease of administration (Ekkekakis, 2009; Murkin & Arango, 2009; Perrey, 2008). NIRS is considered the most realistic technology to measure brain activity during exercise (Ekkekakis, 2009). NIRS has been used to derive data on cerebral blood flow which is reported to increase during exercise suggesting increased neuronal activation which relates to increased cognition (Ide & Secher, 2000; Villringer, et al., 1993). As such, NIRS may identify a relationship between changes in cerebral perfusion and cognitive performance with exercise.

2.9 Study rationale

Although exercise is widely accepted to benefit cognitive performance, most of the research has a focus on healthy adult populations (Marzolini, et al., 2012; Gordon, et al., 2004). Research on the effect of acute exercise in stroke patients is very limited with research primarily involving chronic exercise interventions (Quaney, et al., 2009). Most research supports a positive relationship between exercise and cognitive performance (Chang, et al., 2012; Lambourne & Tomporowski, 2010). However, this has not been sufficiently examined in stroke patients. It is important to examine the effects of exercise on physiological, psychological and cognitive functions in stroke patients to improve cognitive and physical impairments and to reduce the risk of recurrent stroke and long-term disability (Billinger, et al., 2014). Studying the effects of exercise may also develop opportunities to elicit changes in fine motor skills and dexterity which are often impaired after having a stroke (American Stroke Association, 2012).

In adult populations, studies have shown that the most beneficial effects of exercise on cognitive function are observed with continuous, aerobic exercise of a moderate intensity (Chang, et al., 2012). However, the effects of different exercise modes on cognitive function have not been examined in stroke patients and exercise modes prescribed for healthy adults may not be suitable for stroke patients (Durstine, et al., 2009). Many stroke patients may experience difficulty trying to maintain their balance for commonly prescribed exercises in healthy adults such as jogging on a treadmill (Gordon, et al., 2004). Supine or recumbent positions may be recommended for stroke patients to enhance comfort and safety (Pesce, et al., 2009; Gordon, et al., 2004). In addition, physiological changes that occur when postural position is manipulated during different exercise modes may affect cognitive function (Ozgoren, et al., 2012; Kato, et al., 2011). Accordingly, this study involves an acute bout of sub-maximal moderate intensity exercise comparing seated and supine exercise positions on cognitive performance in stroke patients.

Research on exercise duration in healthy adults suggests that 20- to 40-minutes of exercise is required to achieve the most beneficial improvements to cognitive performance (Chang, et al., 2012). As such the exercise duration of this present study is 30-minutes. It is hypothesised that the exercise intensity and duration of this present study will attribute to cognitive improvements after exercise for both seated and supine exercise. This study compares the effects of 30-minutes of sub-maximal moderate intensity exercise in a seated

and supine position on executive function in TIA patients. As a TIA is perceived as a warning sign for impending stroke, the effects of exercise on cognitive performance may be beneficial and implemented in treatment procedures for cognitive impairment in stroke patients (Gommans, et al., 2009). There is currently consensus that exercise should begin as early as possible after a TIA or stroke to elicited greater improvements in cognitive function (Billinger, et al., 2014; Brethour, et al., 2012). However, the earliest time research has examined the effect of exercise on cognitive performance was three weeks after the stroke event (Nilsson et al., 2001). As such, the TIA patients were recruited within one week of their TIA event. This study includes a healthy control group to compare any differences in performance.

It is well established that stroke causes both physical and cognitive impairments (Go, et al., 2013). Executive function is considered to be a cognitive domain frequently impaired among stroke patients (Cumming, et al., 2012; Nys, et al., 2005). In addition, it is suggested that benefits to mental health are most clearly seen through tasks that involve executive function (Chang, et al., 2012). As such, the Stroop task was performed in this present study as it is considered a reliable and valid assessment of executive function (Chang, et al., 2012; Yanagisawa, et al., 2010; Quaney, et al., 2009; Sibley, et al., 2006). Furthermore, the duration of cognitive improvements after acute exercise has not been thoroughly examined in healthy adults or stroke patients. Thus, this study is designed to test the delayed effects of acute exercise on executive function in stroke patients.

It is important to understand the physiological mechanisms which underlie the relationship between exercise and executive function to achieve maximal benefits for cognitive health and function. Therefore, this study involves investigation of cerebral perfusion as several studies support that exercise increases cerebral blood flow, neural activity, oxygenation and total haemoglobin in the prefrontal cortex which relate to improvements in cognitive function (Best, 2010; Ekkekakis, 2009). NIRS will be used to assess cerebral perfusion and haemodynamics (O_2Hb, tHb, HHb, TSI) during exercise and for the cognitive assessment before and after exercise. Although fMRI is the gold standard for imaging the human brain and activity, it is an expensive instrument and is susceptible to movement suggesting it is not suitable for assessing cerebral haemodynamics during exercise. As such, NIRS technology is used to measure cerebral perfusion and haemodynamics as it is non-invasive, portable and the most realistic device to monitor brain activity during exercise with results compatible to fMRI (Cui, et al., 2011; Ekkekakis, 2009; Ide & Secher, 2000).

2.10 Purpose of the current study

The purpose of this study was to examine the effects of an acute bout of sub-maximal moderate intensity exercise in a seated and supine position on executive function in TIA and HC participants. The null hypotheses (H_0) of this present research study are reported below:

- $H_0(1)$: Exercise will not have an effect on executive function.
- $H_0(2)$: There will be no differences between the supine and seated exercise on executive function.
- $H_0(3)$: There will be no differences between the TIA patients and HC participants for their executive function performance on the Stroop task.
- $H_0(4)$: There will be no changes to executive function for the assessment time points proceeding exercise.

The following are the research hypotheses (H_1) for the present study:

- $H_1(1)$: Exercise will have a positive effect on executive function.
- $H_1(2)$: There will be differences between the seated and supine exercise on executive function.
- $H_1(3)$: There will be differences between the TIA patients and HC participants for their executive function performance on the Stroop task.
- $H_1(4)$: The benefits of exercise on executive function will be maintained up to 15-minutes following exercise.

3. Method

3.1 Participants

Nine TIA patients (age: 65.1 ± 10.1 y; height: 169.7 ± 11.3 cm; body mass: 85.8 ± 16.9 kg) including seven males and two females and a healthy control group (HC) of fifteen older adults (age: 61.5 ± 7.1 y; height: 176.6 ± 8.0 cm; body mass: 84.9 ± 16.3 kg) including thirteen males and two females from the Wellington region volunteered for this study. The TIA participants were recruited within one week of having their TIA event. Diagnostic tests (stroke classification, side of body affected) were undertaken and reviewed by specialist neurologists from Wellington Hospital for the TIA participants. To assist with the diagnosis, the National Institutes of Health Stroke Scale (NIHSS) was performed (Appendix B). The NIHSS is used to objectively quantify the impairment caused by a stroke or TIA (Faulkner, et al., 2014). The test scores a specific ability (i.e. motor arm and motor leg function) between 0 (normal function) and 4 (significant impairment) (Adams, et al., 1999). These assessments may be used to establish the degree of independence during hospital admission (McDowell, 1996). The TIA patients that participated in this study were diagnosed with a stroke or high risk TIA (with $ABCD^2$ score ≥ 4; Appendix C), after review by a specialist stroke physician. TIA patients were excluded from this study if they had any of the following: oxygen dependence, uncontrolled angina, unstable cardiac conditions (i.e., atrial fibrillation), uncontrolled diabetes mellitus, major medical conditions, claudication, febrile illness, significant cognitive impairment, immobile, age > 85 years (Faulkner, et al., 2014).

All participants were invited to take part (Appendix D), given information on the study (Appendix E & F) and provided their written informed consent (Appendix G & H) before the commencement of the study. A health history questionnaire (Appendix I), health screening (Appendix J) and a coronary artery disease risk stratification assessment was completed to establish that the control group participants were healthy, asymptomatic of illness, disease or mental disability and free of any injury in order to participate in the study. The TIA participants completed the health history screening and had an electrocardiogram (ECG) assessment to establish appropriate cardiovascular health for this study. None of the participants suffered from colour blindness or attention deficits. This research was conducted in agreement with the guidelines and policies of the institutional ethics committee and New Zealand's health and disability ethics committee (Appendix K).

3.2 Procedures

Participants performed two familiarisation sessions (see section 3.3) and four laboratory-based exercise protocols (see section 3.4; see Figure 2) on a cycle ergometer (Velotron, RacerMate, Seattle, U.S.A.), within a thermo-neutral environment (temperature: 21.3 ± 1.4 ºC; humidity: 39.9 ± 7.4 %; atmospheric pressure: 1009 ± 8 $N \cdot m^2$). The exercise protocols included two continuous, incremental maximal graded-exercise tests (GXT) to volitional exhaustion; one of these tests was performed on a seated cycle ergometer, the other was performed on a cycle ergometer in a supine position. The two remaining tests were sub-maximal exercise tests (on a seated and supine cycle ergometer), performed at a moderate exercise intensity based upon physiological criteria achieved from the initial maximal GXTs. A minimum of 72-hours was required for recovery between each test.

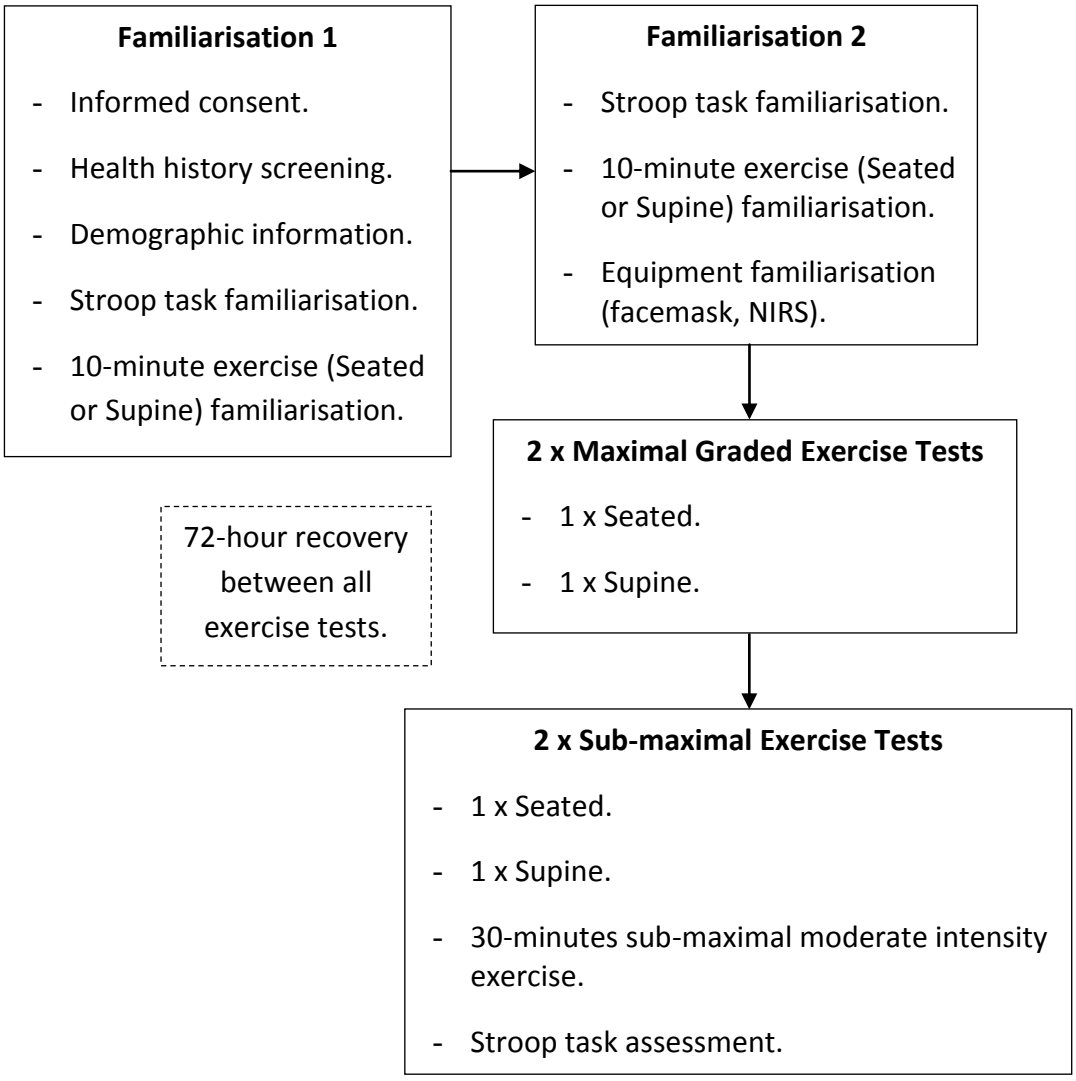


Figure 2. Summary of research procedure for familiarisation and exercise tests.

A facemask was worn during all exercise tests to allow participants to verbally communicate. On-line respiratory gas analysis occurred via a breath-by-breath automatic gas exchange system (Sensormedics Corporation, Yorba Linda, CA, USA). Respiratory variables including oxygen uptake ($\dot{V}O_2$), carbon dioxide ($\dot{V}CO_2$), minute ventilation ($\dot{V}_E$) and respiratory exchange ratio (RER) were continuously recorded throughout all exercise protocols. Volume and gas calibration was performed in accordance with manufacturer's guidelines prior to the start of each test. Throughout each test participants wore a wireless chest strap telemetry system to monitor heart rate (Polar Electro T31, Kempele, Finland) and a portable NIRS device (Artinis Medical Systems BV, Zetten, The Netherlands) to measure cerebral perfusion. The Ratings of Perceived Exertion (RPE) scale (Appendix L) was used to monitor the participant's perception of exertion throughout the exercise tests. The Stroop task (see section 3.5.2) was used to assess executive function before (Baseline), 1.5- (Post) and 15-minutes (15-min Post) after each sub-maximal moderate intensity exercise test.

3.3 Familiarisation

Prior to undertaking the exercise tests, the participant completed two familiarisation sessions that involved becoming accustomed to the equipment, laboratory environment, cycle ergometers and the cognitive test (Stroop task). The initial familiarisation session included the completion of the health history questionnaire and screening and a coronary artery disease risk stratification assessment (Appendix I & J). Accordingly, blood glucose, total cholesterol, blood pressure, smoking status and family history of cardiovascular diseases were assessed. Demographic information was obtained which included the participants' height, body weight, body mass index (BMI), body fat percentage (BF %), measured by bioelectrical impedance analysis (InBody Biospace 230, Los Angeles, USA) and girth measurements of the waist and hip, (Lufkin W606PM, Apex Tools Group, Maryland, USA). After the participants were determined suitable for the study, the participants exercised in a randomised order on either the seated or supine cycle ergometer for 10-minutes at two low intensities (5-minutes at 60 W and 5-minutes at 120 W) which they were likely to encounter in the subsequent exercise tests. Following a 72-hour recovery, the second familiarisation session involved another 10-minutes of low intensity exercise on either the seated or supine ergometer. The participant was familiarised and completed the Stroop task during both familiarisation sessions.

3.4 Exercise tests

The four main exercise tests which proceeded the familiarisation sessions were completed in a semi-randomised order with a minimum 72-hour recovery period between tests. The testing was semi-randomised as the maximal GXTs needed to precede the sub-maximal moderate intensity exercise tests. The participants exercised in a fasted state and were asked not to consume food the morning of any of their exercise tests. Prior to each exercise test, participants remained in a supine position for 10-minutes to allow resting 'Baseline' values for NIRS measures (O_2Hb, HHb, tHb and TSI; see section 3.5.1), blood pressure, heart rate and respiratory variables ($\dot{V}O_2$, $\dot{V}CO_2$, $\dot{V}_E$, and RER) to be acquired. In the proceeding tests, all physical (i.e., power output) and physiological data was concealed from the participants.

3.4.1 Maximal graded exercise tests (GXT).

The seated and supine GXTs were continuous and incremental, commencing at 60 W and increased 12 W per minute. Heart rate, blood pressure and RPE were recorded at the end of each 2-minute stage. Criteria for termination of the maximal GXT was primarily based on volitional exhaustion, although the achievement of ± 10 b·min^{-1} of maximum heart rate and/or a RER value of > 1.00 were used as secondary indicators (Rowland, 1996).

i. Calculation of GET.

In addition to $\dot{V}O_2$peak, individual gaseous exchange thresholds (GET) were determined using the data obtained from both maximal GXTs. Knowledge of the GET markers was important in establishing the exercise intensities that were used in the two subsequent sub-maximal moderate intensity exercise tests (Seated and Supine). GET was calculated using the $\dot{V}$-slope method (Beaver, et al., 1986). This method required the slopes of $\dot{V}O_2$ and $\dot{V}CO_2$ volume curves to be plotted. GET represents the point at which a non-linear relationship exists between $\dot{V}O_2$ and $\dot{V}CO_2$, and it denotes the upper threshold of the moderate intensity exercise domain (see Figure 3; Jones & Poole, 2005). Power outputs equating to GET were calculated for use in the subsequent sub-maximal moderate intensity exercise tests. Three independent researchers verified the interpretation of the $\dot{V}O_2$ data (GET) and the corresponding power outputs.

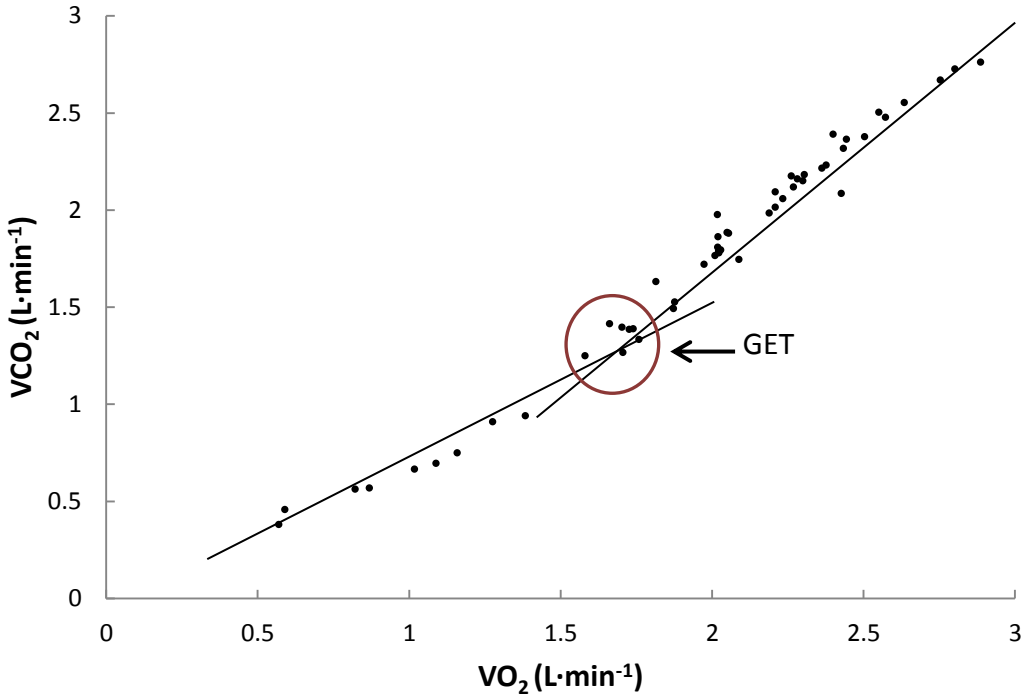
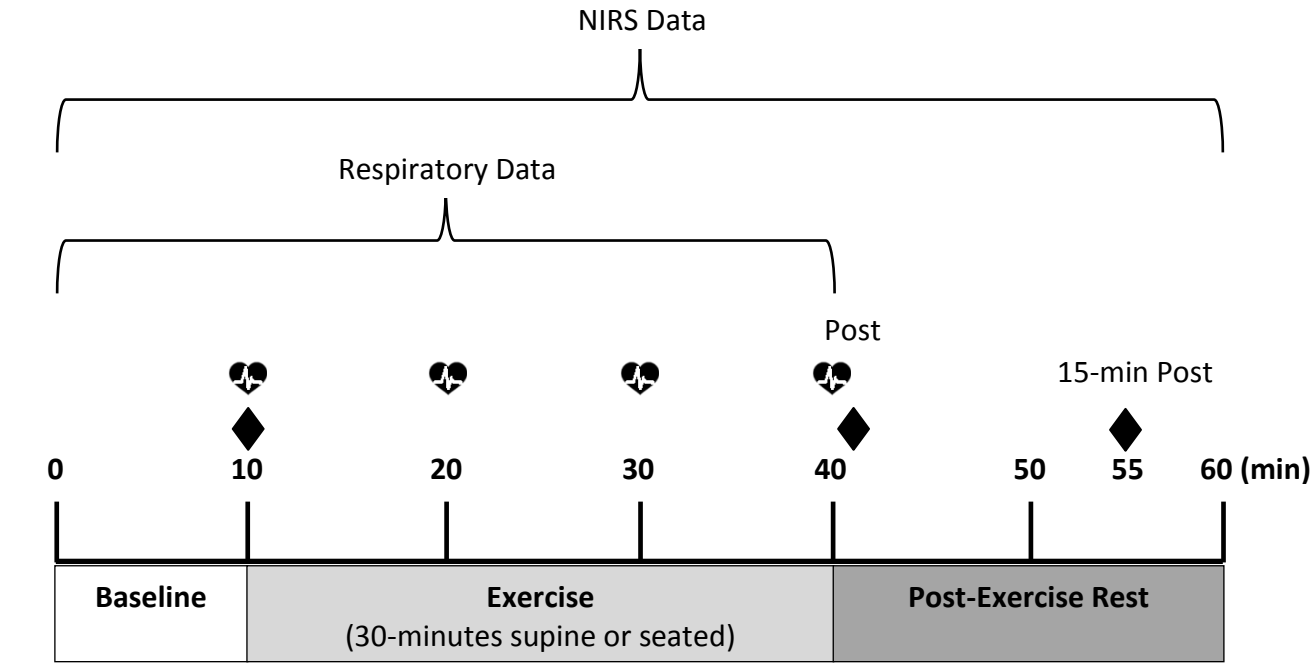


Figure 3. Example of the $\dot{V}$-slope method used to determine GET.

3.4.2 Sub-maximal moderate intensity exercise tests.

Participants performed two sub-maximal exercise tests in a Seated and Supine positon whereby participants cycled continuously for a 30-minute period at moderate exercise intensity. The moderate exercise intensity equated to the power output equivalent to participants' individual GET (see Figure 3). NIRS measures and respiratory variables were continuously recorded throughout the tests, and the participant's blood pressure, heart rate and RPE were recorded every 10-minute during the exercise tests. Prior to and following the sub-maximal moderate intensity exercise tests, participants completed the cognitive task on executive function (Stroop task). The Stroop task was completed following 10-minutes of quiet, supine rest (Baseline) prior to both sub-maximal moderate intensity exercise tests. The Stroop task was then performed 1.5- (Post) and 15-minutes (15-min Post) after completing the sub-maximal moderate intensity exercise bouts (see Figure 4).



◆ = Stroop task assessment; 💓 = Heart rate, blood pressure and ratings of perceived exertion obtained.

Figure 4. Research procedure for sub-maximal moderate intensity exercise tests.

3.5 Measures

3.5.1 NIRS Portalite probe.

A continuous wave NIRS device (Portalite, Artinis Medical Systems BV, Zetten, Netherlands) was used to measure changes in O_2Hb, HHb, tHb and TSI. The NIRS consisted of three light transmitters each separated by a distance of 5 mm. Light was emitted at two wavelengths (± 760 nm and ± 850 nm). The light source and detector were housed in the same holder with a fixed distance of 40 mm, eliciting an average measurement depth of ~17.5 mm (Ferrari, et al., 2004). A differential pathlength factor (DPF) value of 4 was used.

NIRS was used to assess cerebral perfusion during exercise and a protective layer of thin transparent plastic wrap was placed around the NIRS probe to seal and protect the device from sweat. Participants' foreheads were wiped with a gauze pad to make sure that the skin was dry, and to ensure that there was a good contact between the NIRS probe and the forehead. Depending on individual head geometry, the probe was positioned over the

participant's prefrontal cortex between Fp1 and F3[1] for right sided dominant participants and between Fp2 and F4 [2] for left sided dominant participants according to the International 10-20 system of Electrode Placement. This position allowed the probe to be placed above the supra orbital ridge, avoiding the frontal sinuses which may cause readings non-reflective of brain tissue (Murkin & Arango, 2009). For the TIA participants, the side in which their TIA event occurred determined which side the NIRS probe was placed. The probe was attached to the skin with double-sided adhesive tape to ensure that the NIRS probe was securely positioned. A black headband was placed on the forehead covering the probe to reduce the loss of transmitted light from the examined area. The black headband prevented the influence of environmental light affecting the NIRS readings as environmental light can display inaccurate and overestimated results (Artinis Medical Systems BV, 2011). An area of 6 cm around the detector was covered as recommended by the manufactures guidelines.

3.5.2 Executive function (Stroop task).

The Stroop task is considered a common, reliable and easy to administer task to assess executive function (Sibley, et al., 2006; Penner, et al., 2012; Chang, et al., 2012). The Stroop task elicits what is known as the Stroop effect which demonstrates interference in the reaction time of a task which involves presented colour words (Stroop, 1935). Participants were familiarised to the Stroop task in both familiarisation sessions. The Stroop task was completed at Baseline before both sub-maximal moderate intensity exercise tests, and then 1.5- (Post) and 15-minutes (15-min Post) after the exercise test was completed. The Stroop task that was completed immediately after exercise (Post) allowed enough time for the participant to get off the cycle ergometer and be seated at the computer.

The Stroop task (Xavier Educational Software Ltd., Bangor, Wales) was completed by the participants on a computer (HP Compaq Elite 8100 SFF PC, Hewlett Packard, USA) positioned at eye level, 20 inches away from the participant. The participant was presented with a series of colour names (blue, yellow, green, red) in the

[1] FP1 and F3 are part of the international 10/20 system for scalp electrode placement which represents an underlying area of the cerebral cortex. Where, the letter F identifies the frontal lobe location and P identifies the parietal lobe, the odd number 1 and 3 refer to positioning on the right hemisphere.

[2] Fp2, and F4 are part of the international 10/20 system where the even numbers refer to the left hemisphere positioning.

middle of the computer screen on a display area of 20.0" horizontal x 11.3" vertical; 23.0" diagonal (ViewSonic Corporation, Walnut, CA, United States). The colour names appeared individually in a completely randomised order, in lower case letters against a black background. The words appeared in different coloured ink, sometimes matching the colour name (e.g., the word green, in green ink; see Figure 5a) – congruent condition, and sometimes not matching the colour name (e.g., the word red, in yellow ink) – incongruent condition (see Figure 5b).

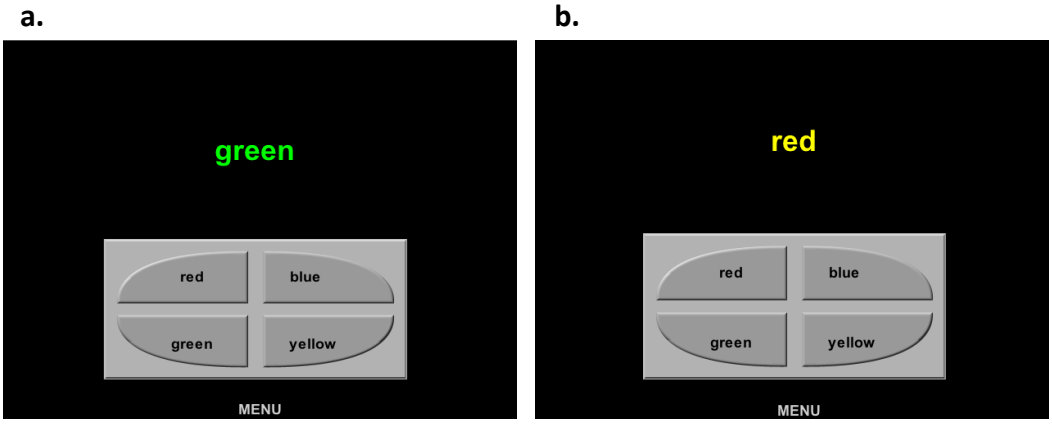


Figure 5. Example of the Stroop task displaying a congruent condition (5a) and incongruent condition (5b).

There were four buttons with the colour names separately displayed on each of these buttons within a light grey box (3.6" width x 1.7" height) one inch beneath the presented colour name, towards the bottom of the computer screen. To facilitate identification of the correct button the colour names on the buttons were presented in black ink. The Stroop task included two separate tasks – the 'word' Stroop and the 'colour' Stroop. The 'word' Stroop task required the participant to read and match the presented word with the correct text. For example, for the word that read yellow, presented in blue ink, the correct answer would be yellow (see Figure 6).

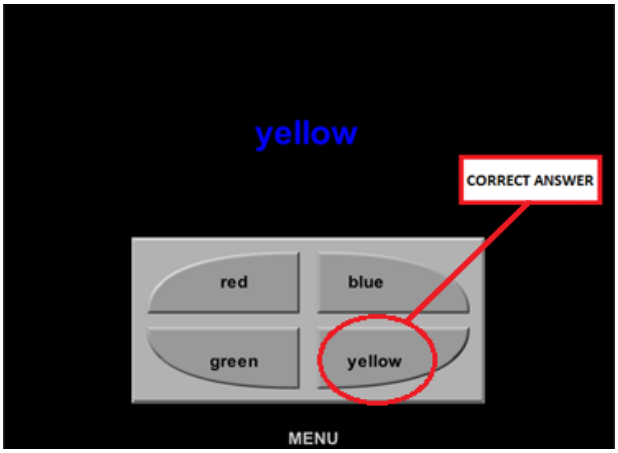


Figure 6. Correct answer of an example for the word Stroop task.

For the 'colour' Stroop task, the participant was required to match the colour ink the word was presented in, ignoring the name of the colour word itself. For example, if the word blue appeared, presented in red ink, the correct answer would be red (see Figure 7). It is suggested that people are more practiced at word reading than naming colours, and as a result, the information is processed faster and there is less interference with word reading than with colour naming (Stroop, 1935). Thus, this study analyses the Stroop interference involving colour naming in attempt to observe greater Stroop interference to be more sensitive to executive function (Durgin, 2000).

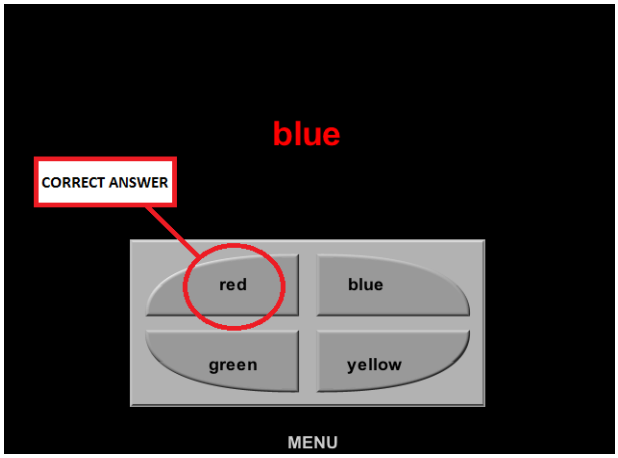


Figure 7. Correct answer of an example for the colour Stroop task.

The participant was instructed to click one of the four buttons, as quickly and accurately as possible when providing their answer. As soon as the participant made a response when they clicked on one of the four buttons, the presented word disappeared and was immediately replaced by another word for the participant to make a response. The Stroop task included 36 trials. The computer was designed to measure the number of correct answers and the total time (s & ms) taken to complete the Stroop task. These details from the Stroop task were recorded at Baseline, Post and 15-min Post following both the Seated and Supine sub-maximal moderate intensity exercise tests.

3.6 Data analysis

3.6.1 NIRS.

Throughout the exercise tests, O_2Hb, HHb, tHb and TSI were sampled and displayed in real time at a frequency of 10 Hz (see Figure 8). The recorded data was subsequently filtered by Gaussian smoothing and exported to Excel for Windows

(Microsoft, Inc., Redmond, Washington) at a down-sampled rate of 0.2 Hz which equated to a five second average for additional analysis. Event markers were used to indicate assessment time points before, during and after the exercise tests. Initially, the bias was set to a value of zero and Baseline data was an average of NIRS measures during the final 1-minute of 10-minute supine rest. All NIRS measures were expressed as a percentage change across each consecutive time point.

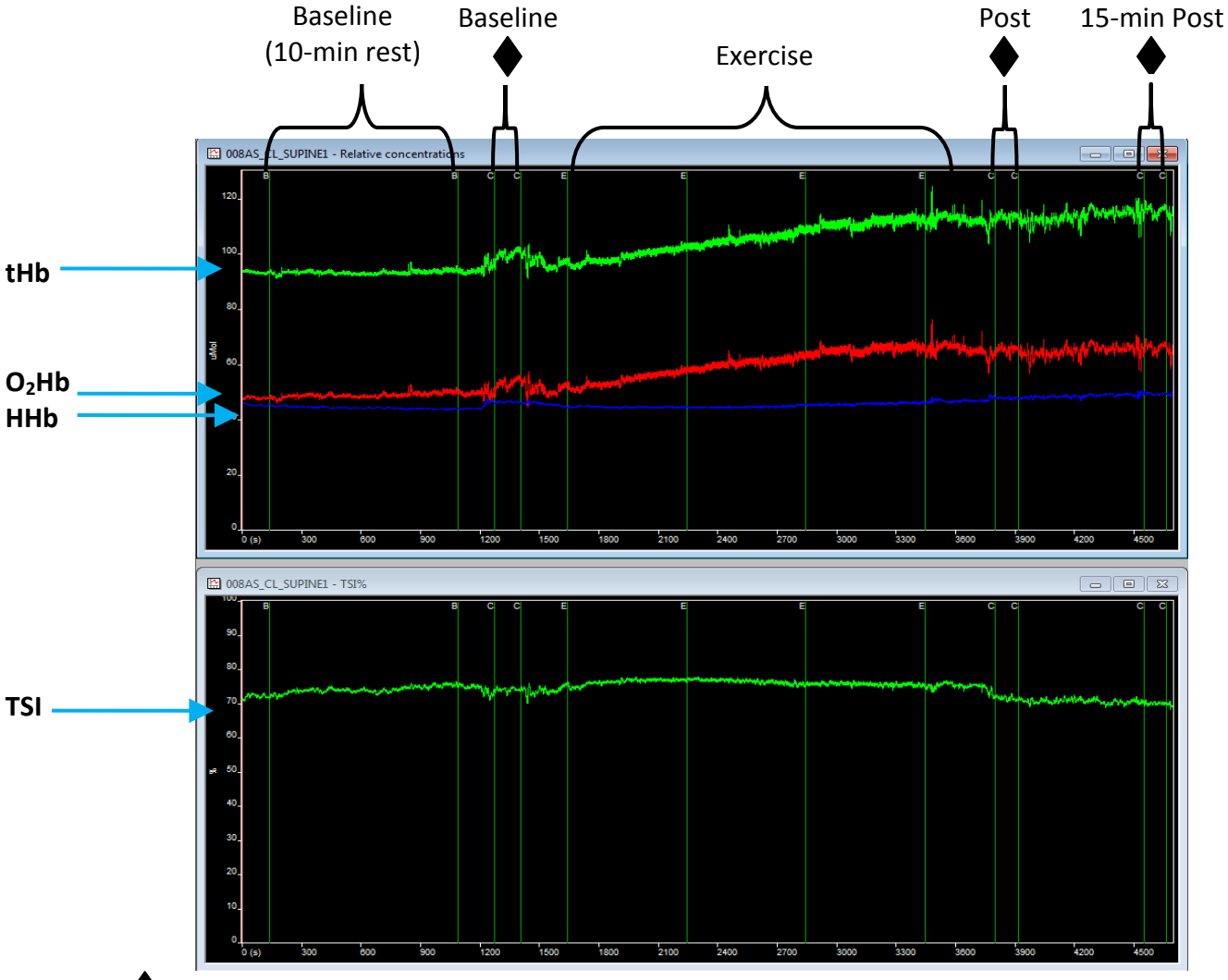


Figure 8. Screen shot of raw NIRS data during Supine exercise.

3.6.2 Statistical analysis.

A series of two-factor repeated measures analysis of variance (ANOVA): Condition (TIA, HC) by Test (Seated, Supine) were used to compare peak physiological ($\dot{V}O_2$peak, $\dot{V}E$. RER, HR, SBP, DBP), physical (PO) and perceptual (RPE) data from the

maximal GXT to volitional exhaustion. A similar analysis was used to compare the absolute and relative $\dot{V}O_2$ and PO at GET between Conditions and Tests.

3.6.3 Executive function (Stroop task).

Independent t-tests were used to compare Stroop task performance at Baseline between TIA and HC participants for both Seated and Supine exercise. A repeated-measures ANOVA: Condition (TIA cf. HC) by Test (Seated cf. Supine) by Time (Baseline, Post, 15-min Post), was used to assess the rate of change in Stroop task performance (time taken and number of correct answers). A similar analysis was used to assess changes in NIRS (O_2Hb, HHb, tHb, TSI) at each assessment point (Baseline, Post, 15-min Post) and during the exercise test (10-, 20-, 30-min). Where assumptions of sphericity were violated, the critical value of F was adjusted by the Greenhouse–Geisser epsilon value from the Mauchley Test of Sphericity. Where significant differences were identified, post-hoc analysis using dependent *t* tests were performed, with an adjustment made via the Bonferroni technique to protect against type 1 error.

3.6.4 Regression analysis.

Regression analysis was used to assess whether the change in O_2Hb, HHb and tHb (independent variables [IV]) (Baseline to Post) accounted for a significant amount of variance in the change in Stroop performance scores (dependent variable [DV]) (Baseline to Post). By altering the order in which each IV was inserted into the regression analysis, it was possible to determine which IV (O_2Hb, HHb or tHb) accounted for the greatest amount of variance in the DVs (change in Stroop performance). Throughout all analyses, alpha was set at 0.05, and adjusted accordingly. All data was analysed using the statistical package SPSS for Windows, PC software, Version 21.

4. Results

4.1 Demographic information

The participants' demographic information can be observed in Table 2. There were no significant differences in demographic values between TIA and HC participants (all $P > 0.05$), with the exception of TC ($t_{(21)} = -2.59$, $P < 0.05$).

Table 2. Mean (±SD) demographic information for TIA and healthy control participants.

	TIA ($N = 9$)	**HC** ($N = 15$)	**95 % CI**	***P*-value**
Age (y)	65.1 ± 10.1	61.5 ± 7.1	-3.63 to 10.92	0.310
Weight (kg)	85.8 ± 16.9	84.9 ± 16.3	-15.03 to 1.31	0.096
Height (cm)	169.7 ± 11.3	176.6 ± 8.0	-13.50 to 15.40	0.893
BMI ($kg \cdot m^2$)	29.8 ± 7.1	27.2 ± 3.9	-2.04 to 7.20	0.260
BF (%)	33.3 ± 11.8	25.8 ± 7.7	-0.97 to 15.94	0.080
Waist (cm)	99.5 ± 13.2	99.9 ± 13.4	-12.27 to 11.38	0.939
Hip (cm)	99.6 ± 15.9	97.8 ± 11.2	-9.95 to 13.48	0.757
Waist:Hip	1.0 ± 0.1	1.0 ± 0.0	-0.06 to 0.03	0.513
TC ($mmol \cdot L^{-1}$)	4.2 ± 1.3	5.4 ± 1.0	-2.18 to -0.24	0.017*
HDL ($mmol \cdot L^{-1}$)	1.2 ± 0.3	1.2 ± 0.4	-0.32 to 0.29	0.914
TC:HDL	3.6 ± 1.4	4.7 ± 1.2	-2.24 to 0.03	0.056
BG ($mmol \cdot L^{-1}$)	5.1 ± 0.7	5.0 ± 0.6	-0.53 to 0.77	0.696
SBP (mmHg)	133.4 ± 15.7	133.0 ± 24.1	-18.30 to 19.18	0.961
DBP (mmHg)	79.3 ± 5.4	76.4 ± 5.1	-1.62 to 7.48	0.195
RHR ($b \cdot min^{-1}$)	59.1 ± 8.9	58.5 ± 6.7	-6.02 to 7.17	0.857

*Significant difference between TIA and HC participants ($P < 0.05$)

CI = Confidence intervals; BMI = Body mass index; BF = Body Fat; TC = Total cholesterol; HDL = High-density lipoprotein; BG = Blood glucose; SBP = Systolic blood pressure; DBP = Diastolic blood pressure; RHR = Resting heart rate.

4.2 Maximal graded exercise tests

4.2.1 Peak data from maximal graded exercise tests.

The participants' peak physiological, physical and perceptual data at maximal functional capacity from the Seated and Supine GXT can be observed in Table 3.

Table 3. Mean (±SD) peak values of variables recorded in the Seated and Supine maximal GXTs to volitional exhaustion for TIA and healthy control participants.

	TIA			HC		
	Seated	**Supine**	**Total**	**Seated**	**Supine**	**Total**
$\dot{V}O_{2peak}$ (ml·kg^{-1}·min^{-1})	28.2 ± 7.7	28.5 ± 9.2	28.4 ± 8.6	39.1 ± 8.9	34.8 ± 8.9	36.9 ± 8.6*
$\dot{V}O_{2peak}$ (L·min^{-1})	2.4 ± 0.6	2.4 ± 0.8	2.4 ± 0.6	3.2 ± 0.6	2.9 ± 0.6	3.1 ± 0.6
$\dot{V}_E$ (L·min^{-1})	87.0 ± 34.5	86.2 ± 35.7	86.6 ± 29.2	115.4 ± 29.7	96.6 ± 23.1	106.0 ± 29.2*
RER	1.1 ± 0.1	1.1 ± 0.1	1.1 ± 0.1	1.1 ± 0.1	1.1 ± 0.1	1.1 ± 0.1
HR (b·min^{-1})	149.0 ± 20.0	141.4 ± 22.9	145.2 ± 15.1	160.3 ± 11.2	146.6 ± 10.1	153.4 ± 15.1
SBP (mmHg)	201.1 ± 25.3	210.9 ± 20.7	206.0 ± 19.1	204.1 ± 18.1	210.0 ± 17.5	207.1 ± 19.1
DBP (mmHg)	88.4 ± 10.1	91.6 ± 9.0	90.0 ± 8.3	87.9 ± 8.2	86.4 ± 8.9	87.1 ± 8.3
RPE	17.0 ± 2.1	17.4 ± 1.9	17.2 ± 1.5	18.1 ± 1.4	18.1 ± 1.2	18.1 ± 1.5
PO (W)	160.5 ± 33.8	149.0 ± 44.4	154.8 ± 42.7	204.9 ± 49.1	173.2 ± 40.9	189.1 ± 42.7

*Significant difference between TIA and HC participants ($P < 0.05$)

$\dot{V}O_2$ = oxygen consumption; GET = Gaseous exchange threshold; $\dot{V}_E$ = Minute ventilation; RER = Respiratory exchange ratio; HR = Heart Rate; SBP = Systolic blood pressure; DBP = Diastolic blood pressure; RPE = Ratings of perceived exertion; PO = Power output; W = Watts.

A significant Test ($F_{(1,22)}$ = 6.3, P < 0.05) and Condition ($F_{(1,22)}$ = 5.6, P < 0.05) main effect was observed for $\dot{V}O_{2peak}$. Significantly higher $\dot{V}O_{2peak}$ values were recorded for the Seated exercise test compared to the Supine exercise test (33.7 ± 8.8 cf. 31.7 ± 9.3 ml·kg^{-1}·min^{-1}, respectively) and for HC compared to TIA (36.9 ± 8.6 cf. 28.4 ± 8.6 ml·kg^{-1}·min^{-1}, respectively; see Table 3).

Test main effects were reported for $\dot{V}_E$ ($F_{(1,22)}$ = 12.3, P < 0.01), HR ($F_{(1,22)}$ = 50.7, P < 0.001) and PO ($F_{(1,21)}$ = 47.5, P < 0.001). Post-hoc analysis demonstrated that significantly higher values for each of the aforementioned parameters were illustrated during the Seated exercise test in comparison to the Supine exercise test ($\dot{V}_E$ = 101.2 ± 32.5 cf. 91.4 ± 29.2 L·min^{-1}; HR = 155 ± 16 cf. 144 ± 17 b·min^{-1}; PO = 183 ± 47 cf. 161 ± 44 W, respectively). A significant Test ($F_{(1,22)}$ = 12.0, P < 0.01) main effect was also reported for SBP, with post-hoc analysis demonstrating higher values during the Supine exercise test compared to the Seated exercise test (210 ± 19 cf. 203 ± 22 mmHg, respectively). There were no Condition main effects for the above physiological parameters (P > 0.05).

4.2.2 $\dot{V}O_2$ and PO data at GET from graded exercise tests.

The $\dot{V}O_2$ (L·min^{-1}) and PO at GET were significantly higher for the HC participants compared to the TIA participants (see Table 4; Both P < 0.01). The $\dot{V}O_2$ (1.5 ± 0.5 cf. 1.4 ± 0.4 L·min^{-1}) and PO (97.9 ± 28.4 cf. 85.9 ± 23.2 W) at GET were also significantly higher for the Seated exercise test compared to Supine exercise test. There were no differences between exercise modality (Seated cf. Supine) and condition (TIA cf. HC) when PO and $\dot{V}O_2$ were expressed as a proportion of maximal values (see Table 4; Both P > 0.05).

Table 4. Mean (±SD) $\dot{V}O_2$ and PO data at GET for TIA and healthy control participants.

	Seated	Supine	Total
TIA			
$\dot{V}O_2$ (L·min^{-1}) @ GET	1.2 ± 0.5	1.3 ± 0.4	1.3 ± 0.4
%$\dot{V}O_2$ (L·min^{-1}) @ GET	51.8 ± 12.3	53.6 ± 7.1	52.7 ± 7.2
PO @ GET	87.3 ± 18.7	80.6 ± 26.0	83.9 ± 23.1
% PO @ GET	54.9 ± 7.8	54.2 ± 6.4	54.6 ± 5.5
HC			
$\dot{V}O_2$ (L·min^{-1}) @ GET	1.8 ± 0.4	1.5 ± 0.4	1.7 ± 0.4*
%$\dot{V}O_2$ (L·min^{-1}) @ GET	56.0 ± 6.5	53.0 ± 8.7	54.5 ± 7.2
PO @ GET	108.6 ± 30.4	91.1 ± 19.8	99.9 ± 23.1*
% PO @ GET	52.8 ± 5.4	53.5 ± 7.8	53.2 ± 5.5

*Significant difference between TIA and HC participants ($P < 0.01$).

4.3 Sub-maximal moderate intensity exercise tests

4.3.1 Time to complete Stroop task.

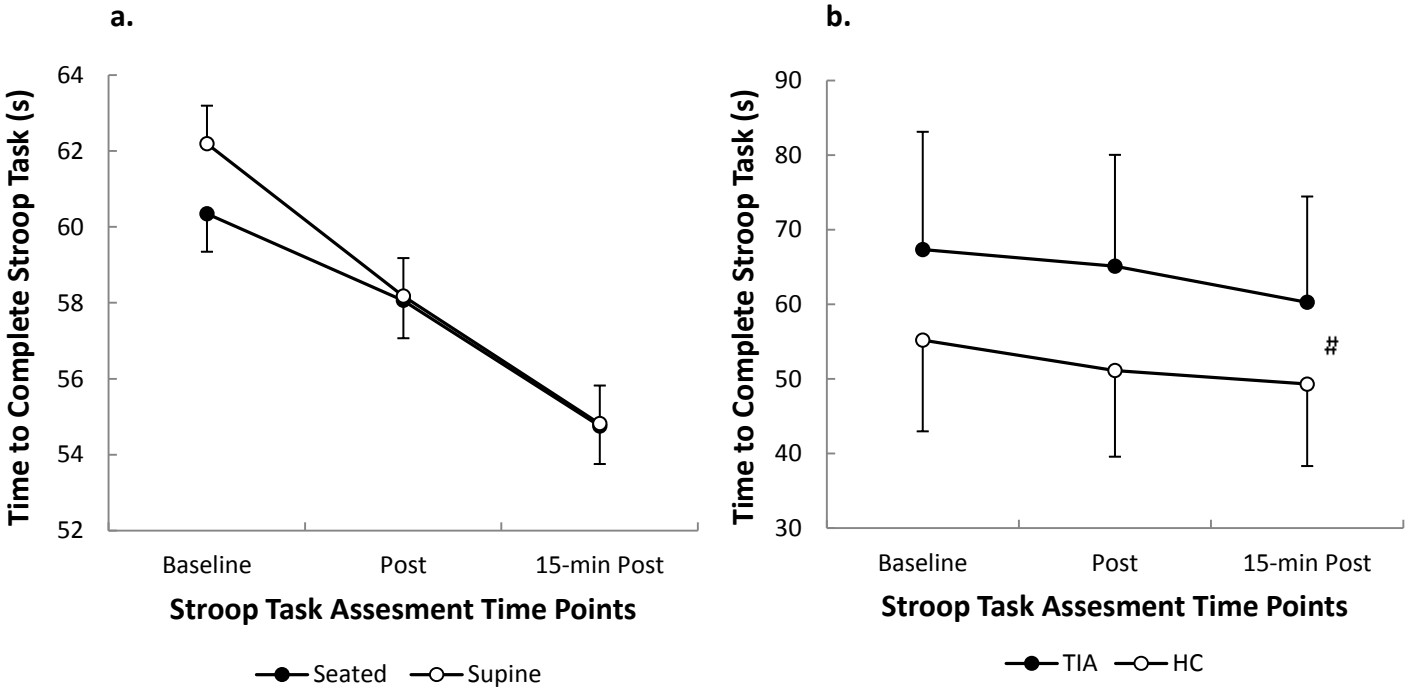
Independent samples t-tests demonstrated that TIA participants had significantly slower completion times compared to the HC participants for their Baseline performance on the Stroop task prior to the Seated ($t_{(22)} = 3.83$, $P = < 0.001$) and Supine ($t_{(22)} = 2.11$, $P < 0.05$) exercise tests (see Table 5).

Table 5. Mean (±SD) Stroop completion times (s) for TIA and healthy control participants at Baseline.

	Seated	Supine
TIA: Stroop completion time	67.2 ± 11.2*	67.4 ± 14.8*
HC: Stroop completion time	53.5 ± 6.5	56.9 ± 9.6

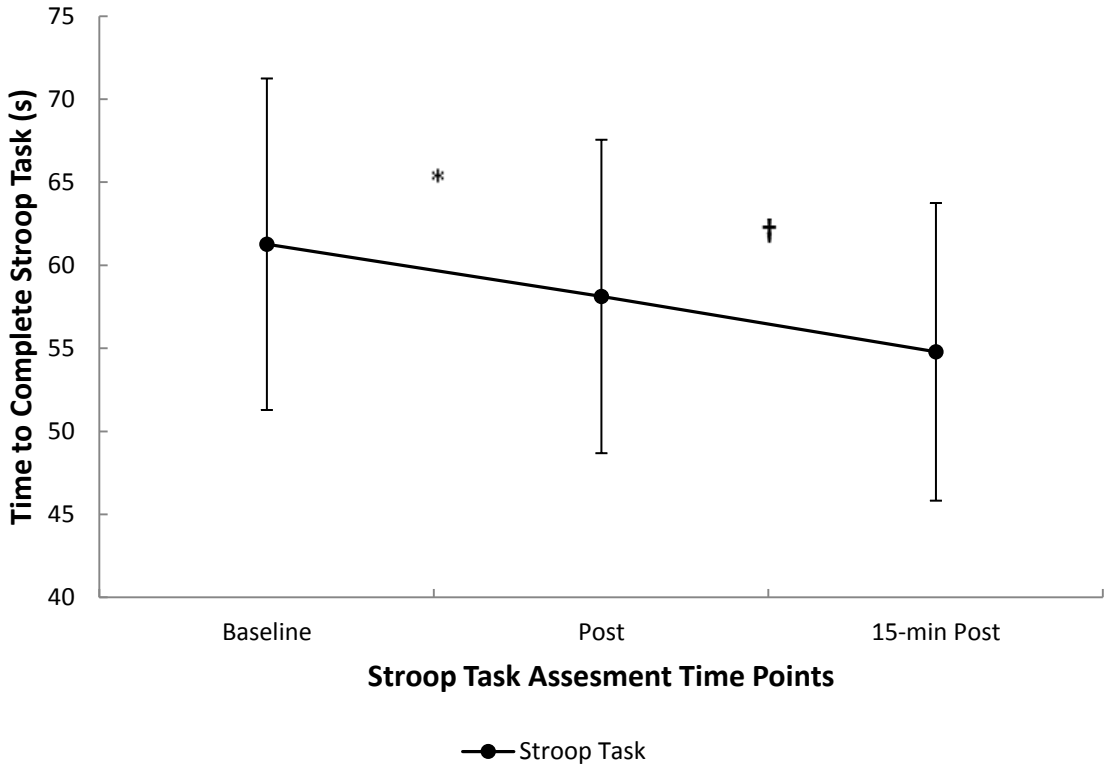
*Significant difference between Seated ($P = < 0.001$) and Supine ($P < 0.05$) exercise for TIA and HC participants at Baseline.

A repeated-measures ANOVA did not demonstrate any interactions between the variables of interest (Condition [TIA cf. HC], Test [Seated cf. Supine; see Figure 9a], Time [Baseline, Post, 15-min]) when assessing changes in Stroop performance ($P > 0.05$). However, Condition ($F_{(1,22)} = 11.9$, $P < 0.01$) and Time ($F_{(2,44)} = 13.4$, $P < 0.001$) main effects were observed. Post-hoc analysis using Tukeys HSD demonstrated that the TIA participants had significantly slower times to complete the Stroop task compared to the HC participants (64.2 ± 13.9 cf. 51.9 ± 10.8 s, respectively; see Figure 9b). There were significant improvements in the Stroop performance between Baseline and Post, Post and 15-min Post (see Figure 10).



Significant difference between TIA and HC participants ($P < 0.01$).

Figure 9. Mean (±SD) time (s) to complete Stroop task for Seated and Supine (9a) exercise and TIA and HC (9b) participants at each assessment time point.

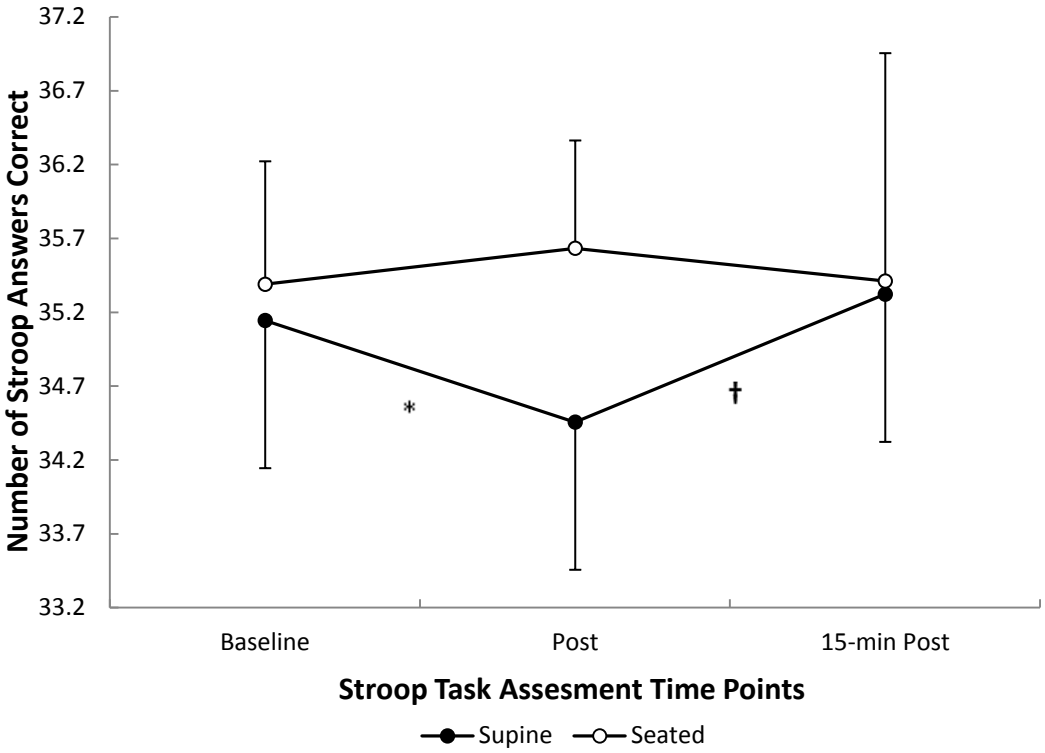


*Significant decrease in time between Baseline and Post exercise ($P < 0.001$); †Significant decrease in time between Post and 15-min Post exercise ($P < 0.001$).

Figure 10. Mean (±SD) time to complete Stroop task at each assessment time point.

4.3.2 Number of correct answers on Stroop task.

There was a significant Test by Time interaction for the number of correct answers for the Stroop task ($F_{(2,44)} = 3.5$, $P < 0.05$). Post-hoc analysis demonstrated a significant decrease in the number of correct Stroop answers between Baseline and Post exercise following Supine exercise (see Figure 11). This was followed by a significant increase in correct answers between Post and 15-min Post Supine exercise. There were no significant changes in the number of correct answers for the Stroop task for the Seated exercise test across all assessment time points.

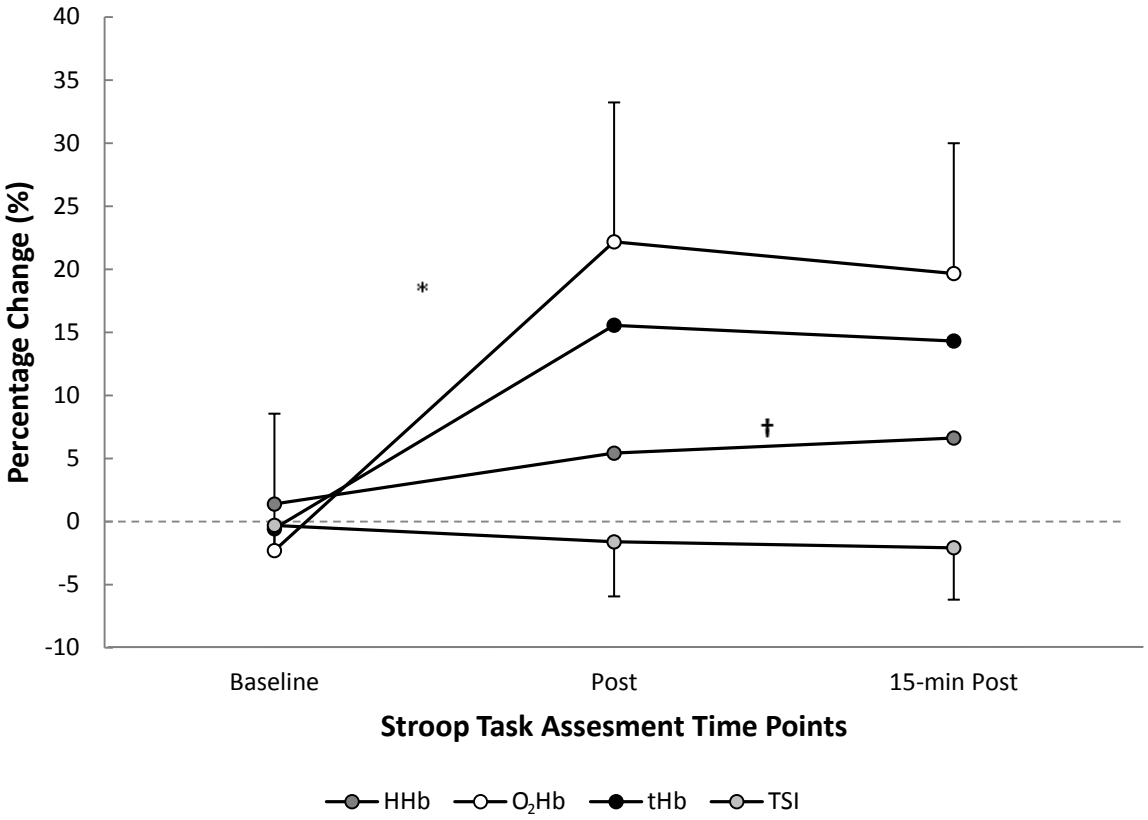


*Significant decrease between Baseline and Post for Supine exercise ($P < 0.05$); †Significant increase between Post and 15-min Post exercise for Supine exercise ($P < 0.05$).

Figure 11. Mean (±SD) number of correct Stroop answers at each assessment time point for the Seated and Supine exercise tests.

4.3.3 NIRS at Baseline and Post exercise.

Time main effects were observed for O_2Hb ($F_{(2,44)} = 136.1$, $P < 0.001$), HHb ($F_{(2,44)} = 56.9$, $P < 0.001$) and tHb ($F_{(2,44)} = 140.2$, $P < 0.001$). Post-hoc analysis demonstrated significant increases in each of the NIRS measures between Baseline and Post (see Figure 12). Further statistical increases were only observed between 1.5- and 15-min Post for HHb. There was no Time main effect for TSI (Baseline = -0.5 ± 1.8 %; Post = -1.3 ± 4.5 %; 15-min Post = -2.3 ± 4.7 %; $P > 0.05$). There was no Condition (TIA cf. HC) or Test (Seated cf. Supine) main effects or for any of the NIRS measures at Baseline and after exercise ($P > 0.05$).



*Significant increase between Baseline and 1.5-min Post for HHb, O_2Hb and tHb (all $P < 0.001$);
†Significant difference between and Post and 15-min Post for HHb ($P < 0.05$).

Figure 12. Percentage change in NIRS measures across different assessment time points for the Stroop task.

i. Regression analysis.

Regression analysis demonstrated that none of the NIRS measures (O_2Hb, HHb or tHb) explained a significant amount of the variance in the change in Stroop task performance (Baseline to Post). This was demonstrated for the entire study sample (N = 24; ($F_{(3,44)}$) = 2.4, $P > 0.05$), and for the respective TIA ($F_{(3,14)}$) = 0.9, $P > 0.05$) and HC ($F_{(3,26)}$) = 1.6, $P > 0.05$) populations. NIRS measures collectively explained 14.2, 16.2 and 15.6 % of the overall variance for the change in Stroop task performance for the entire sample, TIA and HC, respectively.

4.3.4 NIRS and physiological variables during exercise.

The NIRS measures and other physiological data reported during the 30-minute bouts of sub-maximal exercise (Seated and Supine) are provided as supplementary data and can be observed in Appendix M.

5. Discussion

The purpose of this study was to determine the acute effects of moderate intensity seated and supine exercise on executive function in TIA patients. The TIA and healthy control participants performed two 30-minute bouts of sub-maximal exercise on a seated and supine cycle ergometer. The Stroop task assessed executive function before exercise, post exercise and 15-minutes after the Seated and Supine exercise tests. In accordance with the study hypothesis $H_1(1)$, this study showed that an acute bout of sub-maximal exercise improved executive function, as demonstrated by a reduced time to complete the Stroop task. Not only were the benefits observed for both the TIA and healthy control participants ($H_1(3)$), the improvements to executive function were maintained after a 15-minute delay following both exercise tests in agreement with hypothesis $H_1(4)$. There were no differences between the Seated and Supine exercise test on executive function performance which supports the null hypothesis $H_0(2)$ of this research.

5.1 Immediate and delayed effects on time to complete Stroop task

Following 30-minutes of exercise, both TIA and healthy control participants statistically improved their performance on the Stroop task immediately after exercise (Post) regardless of the exercise modality (Seated cf. Supine). This equated to a mean change of 3.1 seconds or a 5.1 % improvement in cognitive performance which reflected faster times to complete the Stroop task between Baseline and Post exercise. Although similar improvements in the time to complete the Stroop task have been demonstrated immediately following an acute bout of exercise with healthy adults (Yanagisawa, et al., 2010; Chang & Etnier, 2009; Sibley, et al., 2006; Tomporowski, 2003), this is the first study which has considered the relationship between acute exercise and executive function within a TIA population. One study which examined acute aerobic exercise and the effects on cognitive function in chronic stroke patients had conflicting results and suggested treadmill exercise was unrelated to the observed improvements in cognitive performance immediately after exercise (Ploughman, et al., 2008). However, the duration (20-minutes) and exercise intensity (70 % HRR) may not have been sensitive enough to elicit cognitive benefits (Ploughman, et al., 2008). In addition, the type of cognitive task used involved information processing and reaction times which are cognitive domains suggested to have small effects or non-significant changes on cognitive function after exercise in healthy adults (Chang, et al., 2012). Research suggests that exercise has the strongest effect on

executive function than other cognitive processes which is supported in this study as the Stroop task demonstrated significant changes in executive function (Chang, et al., 2012).

After the 15-minute delay post exercise (15-min Post), cognitive performance continued to improve regardless of the condition (TIA cf. HC) or exercise modality (Seated cf. Supine) from Post to 15-min Post exercise. There was a mean change of 3.3 seconds or a 5.7 % improvement, reflecting faster times to complete the Stroop task. This study illustrated the positive effects of acute exercise on executive function are sustained up to a 15-minute delay following exercise. These findings are similar to previous research which indicated after 20-minutes of moderate intensity exercise, healthy older adults improved their time to complete the Stroop task immediately and up to 60-minutes after exercise (Barella, et al., 2010). Thereafter times began to slow yet still remained significantly faster than baseline up to 120-minutes following exercise (Barella, et al., 2010).

Although the TIA participants had significantly slower overall times to complete the Stroop task compared to the healthy control participants (see Figure 9b), there were no significant differences when comparing the improvements to cognitive performance between the groups. The findings from this present study also demonstrated that there were no differences for the improved times to complete the Stroop task between the Seated and Supine exercise test which infers that both exercise modalities may be suitable for improving executive function. These findings may be important in the cognitive rehabilitation of stroke patients as either exercise modalities may improve executive function which has further practical implications (see section 5.4).

It is difficult to compare the immediate and delayed effects of exercise on executive function as studies that consider the immediate effects of exercise on cognition in stroke populations have either used different cognitive tasks (Ploughman, et al., 2008) or chronic exercise interventions (Marzolini, et al., 2012; Kluding, et al., 2011; Rand, et al., 2010; Quaney, et al., 2009). Research on the delayed effects of acute exercise on cognitive performance is limited and focused on healthy adults (Barella, et al., 2010). The physiological underpinnings for the observed findings in this present study and previous research are yet to establish the relationship between acute exercise and cognitive performance (Marzolini, et al., 2012; Chang, et al., 2012; Colcombe & Kramer, 2003).

5.2 Physiological reasoning for effects on cognitive performance

A definitive physiological mechanism that explains the improvements in executive function after an acute bout of exercise remains elusive (Swatridge, 2014). One physiological mechanism that has been proposed to possibly mediate the positive relationship between acute exercise and executive function focuses on how exercise enhances the volume and velocity of cerebral blood flow (Barenberg, 2012; Timinkul, et al., 2008). Further to support this theory of increased blood volume and blood flow during exercise, in this present study NIRS was used to measure and monitor tHb (Artinis Medical Systems BV, 2011). The findings from this study showed a 16.1 % increase in tHb from Baseline to Post exercise which was also sustained 15-minutes Post exercise (see Figure 12). The increase in tHb is suggested to equate to greater perfusion (Perrey, 2008). Results of this study are consistent with this possible mechanism as NIRS also detected a statistical increase of 24.5 % in O_2Hb between Baseline and Post which remained significantly higher than Baseline 15-minutes after exercise (see Figure 12). The observed changes to cerebral haemodynamics in this study may suggest that oxygenation of areas in the brain particularly the prefrontal cortex, are relevant for facilitating executive functions (Barenberg, 2012). It is speculated that a stronger elevation of cerebral blood flow and cerebral oxygenation in the prefrontal region of the brain may facilitate and account for the improved effects acute exercise has on cognitive tasks relating to executive function (Seifert & Secher, 2011; Hiura, et al., 2010).

The present study demonstrated a sustained increase in tHb and O_2Hb 15-minutes after exercise which is similar to previous research that showed cerebral oxygenation was 3 to 7.5 % higher after an acute exercise protocol coupled with cognitive tasks across a 30-minute recovery period (Bue-Estes, et al., 2008). Although it is suggested that increased cerebral blood flow improves executive functions after exercise, this remains unclear as blood flow regulation is fast and rapidly decreases upon the cessation of exercise (Best, 2010). Therefore, this does not support an explanation for the delayed cognitive improvements observed in this study as participants continued to reduce their time to complete the Stroop task 15-minutes after exercise. In addition, it is difficult to associate the delayed improvements in Stroop performance with the delayed effects of cerebral blood flow as most research examines cerebral haemodynamics during exercise rather than following exercise (Ide & Secher, 2000). Although regression analysis demonstrated that NIRS measures (tHb, O_2Hb, HHb) collectively explained 16.2, 15.6 and 14.2 % of the overall variance for the change in Stroop task performance for the TIA, healthy controls

and the entire population sample, respectively, it was not significant. This suggests there are other physiological mechanisms besides the NIRS measures that should be considered to have an effect on cognitive performance after acute exercise such as BDNF or levels of neurotransmitters.

Although research has suggested physiological mechanisms that mediate improvements to executive function such as angiogenesis, neurogenesis in the hippocampus, the up-regulation of neurotrophins and growth factors such as BDNF (Barenberg, 2012; Yanagisawa, et al., 2010; Best, 2010). These mechanisms are generally adaptations observed with chronic exercise rather than acute exercise. Regardless of the positive role BDNF may also play towards enhanced cognitive function via improved synaptic transmission, the suggested time course of BDNF is considered very short for peripheral levels in humans (Huang, et al., 2014). As such, BDNF levels would not be consistent with the time frame in which the cognitive improvements occurred in this present study (Swatridge, 2014; Huang, et al., 2014; Schinder & Poo, 2000).

Research suggests a more probable physiological explanation for the positive effects of exercise on cognitive function relates to the production of neurotransmitters such as norepinephrine and dopamine (Barenberg, 2012; Best, 2010; Meeusen & De Meirleir, 1995). Studies have shown that these neurotransmitters are up-regulated and increase with exercise (Winter, et al., 2007; Meeusen & De Meirleir, 1995). The metabolism of these neurotransmitters in the prefrontal cortex is thought to play a crucial role in the control of executive function processes (Barenberg, 2012; Robbins & Arnsten, 2009). Increases in plasma catecholamine concentrations have shown a prolonged response generally lasting up to 30-minutes after exercise cessation (Meeusen & De Meirleir, 1995). Whereas, levels of brain neurotransmitters can be significantly elevated and take a prolonged time to metabolise anywhere from 20- to 120-minutes after exercise cessation (Goekint, et al., 2012; Meeusen & De Meirleir, 1995). This may reflect the increasing cognitive improvements observed on the Stroop task Post exercise and after the 15-minute delay as a result of metabolic recovery which future research is recommended to further explore (Lambourne & Tomporowski, 2010; Meeusen & De Meirleir, 1995).

Another possible theory that mediates these physiological mechanisms is the theory of arousal which involves the inverted-U hypothesis (Chang, et al., 2012; McMorris, 2008). Processes that relate to physiological arousal such as increases in catecholamines or neurotrophins may drive improvements in cognitive performance

(Pennington & Hanna, 2013; Vaynman & Gomez-Pinilla, 2005). Accordingly, it is predicted that moderate intensity exercise produces moderate levels of physiological arousal which would create the most favourable effects on cognitive performance in adults (Chang, et al., 2012; McMorris, 2008). However, it appears research has not consistently supported this notion (Pennington & Hanna, 2013; Chang & Etnier, 2009). Furthermore, it is thought that exercise around GET is associated with immediate increases in the plasma levels of catecholamines, adrenocorticotropic hormone, vasopressin and β-endorphin in the peripheral blood circulation (Dishman & O'Connor, 2009; McMorris, et al., 2008; Chmura, et al., 1994). These are considered to reflect the increased secretion of neurotransmitters in the central nervous system which consequently may enhance cognitive performance (Barenberg, 2012; Anish, 2005). However, the link between these physiological mechanisms with exercise and executive function are yet to be fully understood and need to be explored in further detail. Nonetheless, an impression of how exercise may affect executive functioning is given.

5.3 Immediate and delayed effects on Stroop task accuracy

The effects of exercise on Stroop accuracy did not follow the same pattern as observations for the time to complete the Stroop task in this present study (see section 5.1). There were no significant changes in the number of correct answers on the Stroop task at Post and 15-min Post following the Seated exercise test (see Figure 11). This is similar to previous research which has shown accuracy was not influenced by acute exercise (Kamijo, et al., 2007; Hillman, et al., 2003). Furthermore, there appeared to be a ceiling effect as many participants achieved the maximum Stroop score of 36 at Baseline. The ceiling effect may undermine the ability to interpret the observed results in Stroop task accuracy as the participants could not have significantly improved their performance after exercise (Dean, et al., 2012). Participants who achieved close to the maximum score also had little room for improvement after exercise (see results section 4.3.2). Conversely, this also suggests that there was more room for error which may relate to the decrement in cognitive performance which was observed immediately following the Supine exercise test, regardless of the condition (TIA cf. HC). This was followed by a significant increase in cognitive performance after the 15-minute delay as participants increased the number of correct answers on the Stroop task. These immediate and delayed effects after the Supine exercise test are consistent with research that suggests cognitive tasks administered between 0- to 10-minutes after exercise have significant negative effects on performance

whereas cognitive tasks administered 11- to 20-minutes after exercise observe the largest positive effects (Chang, et al., 2012). However, this does not support the non-significant changes in Stroop task accuracy after (Post, 15-min Post) the Seated exercise test. The change in body position during exercise may explain the differences as the Stroop task was performed in an upright, seated position. As physiological responses are affected by different postural positions, this may have further affected underlying mechanisms that may influence cognitive performance such as the change in cerebral blood flow (Ozgoren, et al., 2012).

These findings are difficult to interpret as there has been no previous research that compares cognitive function between different exercise modalities in stroke patients. In addition, most research that uses the Stroop task as a method of cognitive assessment focuses on the time response rather than accuracy. It is possible that although Stroop task completion times may improve after exercise, the accuracy on this task may decrease suggesting further study to acknowledge the number of errors and completion time for the Stroop task independently in future tests. In addition, the decrement in cognitive performance immediately after the Supine exercise test demonstrated in the present study is similar to the effects of high intensity exercise on cognitive performance. Previous studies have suggested that high intensity exercise may be detrimental to cognitive function immediately after exercise due to elevated stress hormones and fatigue (Blanton, et al., 2012; Reynolds & Nicolson, 2007; Brisswalter, et al., 2002). Although this study examined moderate intensity exercise, fatigue may have been a factor during the Supine exercise test as participants were likely to be more accustomed to exercising in an upright position compared to a supine position. This is further supported by research on healthy adults which compared cycling at different recumbent angles and suggested there was a greater rate of fatigue with supine exercise (Egaña, et al., 2013). Cognitive performance was negatively affected immediately after exercise as a result of this fatigue (Egaña, et al., 2013).

5.4 Practical implications

The aforementioned findings of this present study demonstrate that the immediate and delayed effects of exercise may have several practical implications which relate to improving executive function following a TIA. The novelty and importance of these findings highlight that an acute sub-maximal bout of moderate intensity exercise contributes towards facilitating executive function in TIA participants where cognitive

improvements are sustained for at least 15-minutes after exercise. These results may also have the same benefit for chronic stroke patients and moderate intensity exercise could be considered as a method to enhance cognitive rehabilitation following a stroke.

There are currently limited cognitive rehabilitation strategies for executive function, a cognitive domain most frequently affected by stroke (Kluding, et al., 2011; Rand, et al., 2010). Improvements to executive function may have important implications towards improving common disabilities with stroke and enhancing a stroke patient's ability to perform activities of daily living (Barenberg, 2012). Executive function improvements may also contribute positive effects towards the ability to evaluate and problem solve situations, manage and control emotional responses and improve attention and concentration levels which in turn may improve their overall quality of life (Kluding, et al., 2011).

The findings from this research suggest that while there were no differences in cognitive improvements on response time on the Stroop task between exercise modalities, seated exercise may be more suitable for TIA or stroke patients. Although the time to complete Stroop task improved, the findings from this research suggest that supine exercise may increase the number of errors on executive function tasks which was reflected by decrements in Stroop task accuracy immediately following the Supine exercise test. Additionally, supine exercise may not be appropriate for stroke patients as high blood pressure is the predominating risk factor for stroke (National Stroke Foundation, 2012). Supplementary data from this study demonstrated that during the Supine exercise test, systolic and diastolic blood pressures were significantly higher compared to the Seated exercise test (Appendix M). It was also noted that several TIA participants (N = 4) were unable to complete 30-minutes of continuous Supine exercise and required brief intermittent rest as they reported feelings of exhaustion and fatigue. This is similar to previous research that suggested supine exercise facilitates a greater rate of fatigue (Egaña, et al., 2013). Regardless of the effects both exercise modalities had on cognitive performance after exercise, the findings from this study recommend seated exercise over supine exercise as a precautionary measure to avoid higher blood pressure and greater fatigue during exercise and an increased number of errors on executive function tasks immediately after exercise.

5.5 Strengths and limitations

A limitation of this study was the relatively small sample size (TIA: $N = 9$ cf. HC: $N = 15$). It was initially anticipated that a higher number of TIA patient referrals would be received from Wellington Hospital. Furthermore, any outliers observed in a smaller sample size have a greater effect on the statistical significance of the results compared to larger sample sizes. Additionally, some TIA patient referrals were not suitable to participate due to mobility issues with the supine cycle ergometer which further supports the use of seated exercise in TIA patients. For this reason, these findings cannot be generalised to the wider stroke community based on this study alone and should be considered preliminary.

Although there were no differences in participant demographics between the TIA patients and healthy controls, the ratio of men to women was disproportionate. The male to female ratio (20 males to 4 females) limits the study as gender has been shown to significantly moderate the effects of exercise on cognitive performance in samples including both men and women (Chang, et al., 2012). It has been suggested that while exercise benefits both genders, there is some evidence that cognitive benefits may be greater to women dependent on the presence of oestrogen (Bherer, et al., 2013; Colcombe & Kramer, 2003). Oestrogen is considered to have a neuro-protective role which may contribute to larger cognitive benefits for women than for men (Colcombe & Kramer, 2003). However, these findings have been chronic adaptations of exercise interventions not after acute exercise.

This study was limited by the side of the brain the TIA event occurred on for the TIA patients. The right hemisphere is responsible for processing temporal and spatial relationships, expressing and recognising emotions, and analysing non-verbal information. The left hemisphere is responsible for producing and understanding language, thoughts, logic, words and numbers which associates more to executive functions (Organisation for Economic Co-operation and Development: OECD, 2007). As such, the cognitive performance for the TIA participants may have been subject to greater variability as executive functions may be further impaired if the TIA occurred in the left hemisphere.

Additionally, the current physical fitness status of the healthy control and TIA participants may have limited this study. It has been reported that fitness levels moderate the effects of exercise on cognitive performance (Chang, et al., 2012). Positive effects on cognition have been observed in highly fit participants, negligible effects were observed

for moderately fit participants, and negative effects were evident in low fit participants during and immediately after exercise (Chang, et al., 2012). This study attempted to account for this discrepancy by individualising power outputs equivalent to the participant's GET, and peak values obtained from the maximal graded exercise tests which was a strength of this study. However, higher aerobic fitness in older adults is suggested to reduce the loss of brain volume in regions that mediate executive function (Ratey & Loehr, 2011; Erickson, et al., 2009). As a result of this positive consequence, greater fitness levels are associated with more efficient performance of executive function tasks and increased activity in brain regions involved during cognitive tasks (Ratey & Loehr, 2011; Kramer, et al., 2004; Colcombe & Kramer, 2003). In addition, participants with higher fitness levels may have been more comfortable and accustomed to exercising for the duration of the exercise test compared to less fit participants. Nonetheless, it has been suggested that fitness levels do not moderate the effects when cognitive tasks are performed after a delay (Chang, et al., 2012). This highlights a strength of this present study as the Stroop task was also assessed after a 15-minute delay post exercise.

Few studies have examined the delayed effects of acute exercise on cognition in stroke patients. Therefore, the cognitive assessment (Stroop task) performed 15-minutes after exercise adds vigour to this study. Furthering knowledge on the duration of the cognitive improvements is an important part of understanding the potential mechanisms that underlie the relationship between exercise and cognitive function (Barella, et al., 2010). This element of the study may help develop the ability to prescribe acute exercise to stroke patients as a means of benefiting their cognitive function. Nevertheless, it is possible for further positive effects to occur after this 15-minute delay and research that conducts beyond this period may determine the long-lasting duration of the benefits of exercise on cognitive performance.

5.6 Recommendations for future research

Research on the relationship between acute exercise and cognitive function is limited in stroke populations as most studies involve healthy adult populations. It is recommended that future research should examine this relationship in further detail among stroke patients. Future research should include larger sample sizes and examine the effects on cognitive function over a longer delay period following exercise. Although there are suggested physiological mechanisms that demonstrate possible explanations for the effects of acute exercise on cognitive performance, there is little known about the exact

underlying mechanisms responsible for the cognitive improvements observed in stroke patients.

Additional research identifying the underpinning physiological mechanisms is recommended with the further use of NIRS. Transcranial Doppler tests may also provide information that may link changes in blood velocity and exercise to improvements to cognitive function. The relationship between the effect of exercise and neurotransmitters on cognitive function should be explored using non-invasive techniques such as magnetic resonance spectroscopy or electroencephalography which may be more suitable for research in stroke patients. This line of research may provide further information about the effects of exercise on stroke patient's cognitive health and identify which exercise protocol elicits the most beneficial improvements to cognitive function in stroke patients. Future research should have a particular focus on how exercise can improve the cognitive impairments observed after stroke.

As an observational note, when the TIA participants were aware of their errors on the Stroop task, it was noticed that a few of the TIA participants sometimes became flustered, anxious or frustrated upon making their mistake on the Stroop task. Although these are common emotional disturbances that can occur after a TIA or stroke, there is the potential that their psychological deficits influenced their remaining performance on the Stroop task. This observation suggests future research to consider the effects of exercise on psychological mechanisms that may influence cognitive performance.

6. Conclusion

This study demonstrated that an acute bout of seated and supine exercise may improve executive function performance (as determined by the Stroop task) in TIA patients and HC participants. The time to complete the Stroop task continued to improve immediately after and 15-minutes following both exercise tests. However, the number of correct answers on the Stroop task decreased immediately after and improved 15-minutes after the Supine exercise test. Systolic and diastolic blood pressures were significantly higher during the Supine exercise test which may be a risk for stroke patients. As an observation TIA participants were more fatigued during the Supine exercise test. The exact mechanism that provides explanation for the enhanced cognitive performance after exercise is not yet fully understood. It is possible that the observed increases for cerebral oxygenation and total haemoglobin facilitate improvements to cognitive performance. However, this was not significant and other possible mechanisms that may mediate this relationship include heightened arousal and increased neurotransmitters. Nevertheless, future research is needed to ascertain whether these mechanisms are relevant to stroke populations. Further detail is needed to specify the most beneficial exercise intervention to improve executive function following stroke. It would be recommended that exercise for stroke patients includes moderate intensity seated exercise to elicit improvements to executive functions in a safer manner.

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Appendices

Cognitive Processes Involved in Executive Function

- ***Working memory.***

  The ability and capacity to temporarily process, organise and manipulate information in short term memory to complete a task (Cherry, 2013).

- ***Inhibition.***

  The ability to stop and think at an appropriate time before acting which allows time to evaluate the situation and impact of what is said or done (Chudler, 2009).

- ***Emotional control.***

  The ability to manage emotional responses with rational thought to achieve goals, complete tasks, or to control and direct behaviour (Goldstein, et al., 2013).

- ***Initiation.***

  The ability to begin a task or activity and to independently generate ideas, responses, or problem solving strategies (Diamond, 2012).

- ***Planning/Organisation.***

  The ability to manage future oriented tasks along with the development and maintenance of systems that monitor and manage information or materials (Meltzer, 2007).

- ***Self-monitoring/Self-regulation.***

  The ability to problem solve with observation of one's own performance and recognition of mental, physical, environmental and social factors involved. Self-regulation is an observation of problem solving which refers to the capacity to evaluate the effectiveness of decisions made (Nevid, 2013).

- ***Attention.***

  The ability to take notice and concentrate on the surroundings, something or someone without distractibility, fatigue, or boredom (Diamond, 2012).

National Institutes of Health Stroke Scale (NIHSS)

NIH STROKE SCALE

Patient Identification. ___ ___-___ ___ ___-___ ___ ___

Pt. Date of Birth ___ ___/___ ___/___ ___

Hospital _____(___ ___-___ ___)

Date of Exam ___ ___/___ ___/___ ___

Interval: [ ] Baseline [ ] 2 hours post treatment [ ] 24 hours post onset of symptoms ±20 minutes [ ] 7-10 days
[ ] 3 months [ ] Other _____(___ ___)

Time: ___ ___:___ ___ [ ]am [ ]pm

Person Administering Scale _____

Administer stroke scale items in the order listed. Record performance in each category after each subscale exam. Do not go back and change scores. Follow directions provided for each exam technique. Scores should reflect what the patient does, not what the clinician thinks the patient can do. The clinician should record answers while administering the exam and work quickly. Except where indicated, the patient should not be coached (i.e., repeated requests to patient to make a special effort).

Instructions	Scale Definition	Score
1a. Level of Consciousness: The investigator must choose a response if a full evaluation is prevented by such obstacles as an endotracheal tube, language barrier, orotracheal trauma/bandages. A 3 is scored only if the patient makes no movement (other than reflexive posturing) in response to noxious stimulation.	0 = **Alert;** keenly responsive. 1 = **Not alert;** but arousable by minor stimulation to obey, answer, or respond. 2 = **Not alert;** requires repeated stimulation to attend, or is obtunded and requires strong or painful stimulation to make movements (not stereotyped). 3 = Responds only with reflex motor or autonomic effects or totally unresponsive, flaccid, and areflexic.	_____
1b. LOC Questions: The patient is asked the month and his/her age. The answer must be correct - there is no partial credit for being close. Aphasic and stuporous patients who do not comprehend the questions will score 2. Patients unable to speak because of endotracheal intubation, orotracheal trauma, severe dysarthria from any cause, language barrier, or any other problem not secondary to aphasia are given a 1. It is important that only the initial answer be graded and that the examiner not "help" the patient with verbal or non-verbal cues.	0 = **Answers** both questions correctly. 1 = **Answers** one question correctly. 2 = **Answers** neither question correctly.	_____
1c. LOC Commands: The patient is asked to open and close the eyes and then to grip and release the non-paretic hand. Substitute another one step command if the hands cannot be used. Credit is given if an unequivocal attempt is made but not completed due to weakness. If the patient does not respond to command, the task should be demonstrated to him or her (pantomime), and the result scored (i.e., follows none, one or two commands). Patients with trauma, amputation, or other physical impediments should be given suitable one-step commands. Only the first attempt is scored.	0 = **Performs** both tasks correctly. 1 = **Performs** one task correctly. 2 = **Performs** neither task correctly.	_____
2. Best Gaze: Only horizontal eye movements will be tested. Voluntary or reflexive (oculocephalic) eye movements will be scored, but caloric testing is not done. If the patient has a conjugate deviation of the eyes that can be overcome by voluntary or reflexive activity, the score will be 1. If a patient has an isolated peripheral nerve paresis (CN III, IV or VI), score a 1. Gaze is testable in all aphasic patients. Patients with ocular trauma, bandages, pre-existing blindness, or other disorder of visual acuity or fields should be tested with reflexive movements, and a choice made by the investigator. Establishing eye contact and then moving about the patient from side to side will occasionally clarify the presence of a partial gaze palsy.	0 = **Normal.** 1 = **Partial gaze palsy;** gaze is abnormal in one or both eyes, but forced deviation or total gaze paresis is not present. 2 = **Forced deviation,** or total gaze paresis not overcome by the oculocephalic maneuver.	_____

NIH STROKE SCALE

Patient Identification. ___ ___-___ ___ ___-___ ___ ___

Pt. Date of Birth ___ ___/___ ___/___ ___

Hospital _____(___ ___-___ ___)

Date of Exam ___ ___/___ ___/___ ___

Interval: [ ] Baseline [ ] 2 hours post treatment [ ] 24 hours post onset of symptoms ±20 minutes [ ] 7-10 days
[ ] 3 months [ ] Other _____(___ ___)

3. Visual: Visual fields (upper and lower quadrants) are tested by confrontation, using finger counting or visual threat, as appropriate. Patients may be encouraged, but if they look at the side of the moving fingers appropriately, this can be scored as normal. If there is unilateral blindness or enucleation, visual fields in the remaining eye are scored. Score 1 only if a clear-cut asymmetry, including quadrantanopia, is found. If patient is blind from any cause, score 3. Double simultaneous stimulation is performed at this point. If there is extinction, patient receives a 1, and the results are used to respond to item 11.	0 = **No visual loss.** 1 = **Partial hemianopia.** 2 = **Complete hemianopia.** 3 = **Bilateral hemianopia** (blind including cortical blindness).	_____
4. Facial Palsy: Ask – or use pantomime to encourage – the patient to show teeth or raise eyebrows and close eyes. Score symmetry of grimace in response to noxious stimuli in the poorly responsive or non-comprehending patient. If facial trauma/bandages, orotracheal tube, tape or other physical barriers obscure the face, these should be removed to the extent possible.	0 = **Normal** symmetrical movements. 1 = **Minor paralysis** (flattened nasolabial fold, asymmetry on smiling). 2 = **Partial paralysis** (total or near-total paralysis of lower face). 3 = **Complete paralysis** of one or both sides (absence of facial movement in the upper and lower face).	_____
5. Motor Arm: The limb is placed in the appropriate position: extend the arms (palms down) 90 degrees (if sitting) or 45 degrees (if supine). Drift is scored if the arm falls before 10 seconds. The aphasic patient is encouraged using urgency in the voice and pantomime, but not noxious stimulation. Each limb is tested in turn, beginning with the non-paretic arm. Only in the case of amputation or joint fusion at the shoulder, the examiner should record the score as untestable (UN), and clearly write the explanation for this choice.	0 = **No drift;** limb holds 90 (or 45) degrees for full 10 seconds. 1 = **Drift;** limb holds 90 (or 45) degrees, but drifts down before full 10 seconds; does not hit bed or other support. 2 = **Some effort against gravity;** limb cannot get to or maintain (if cued) 90 (or 45) degrees, drifts down to bed, but has some effort against gravity. 3 = **No effort against gravity;** limb falls. 4 = **No movement.** UN = **Amputation** or joint fusion, explain: _____ **5a. Left Arm** **5b. Right Arm**	_____ _____
6. Motor Leg: The limb is placed in the appropriate position: hold the leg at 30 degrees (always tested supine). Drift is scored if the leg falls before 5 seconds. The aphasic patient is encouraged using urgency in the voice and pantomime, but not noxious stimulation. Each limb is tested in turn, beginning with the non-paretic leg. Only in the case of amputation or joint fusion at the hip, the examiner should record the score as untestable (UN), and clearly write the explanation for this choice.	0 = **No drift;** leg holds 30-degree position for full 5 seconds. 1 = **Drift;** leg falls by the end of the 5-second period but does not hit bed. 2 = **Some effort against gravity;** leg falls to bed by 5 seconds, but has some effort against gravity. 3 = **No effort against gravity;** leg falls to bed immediately. 4 = **No movement.** UN = **Amputation** or joint fusion, explain: _____ **6a. Left Leg** **6b. Right Leg**	_____

NIH STROKE SCALE

Patient Identification. ___ ___-___ ___ ___-___ ___ ___

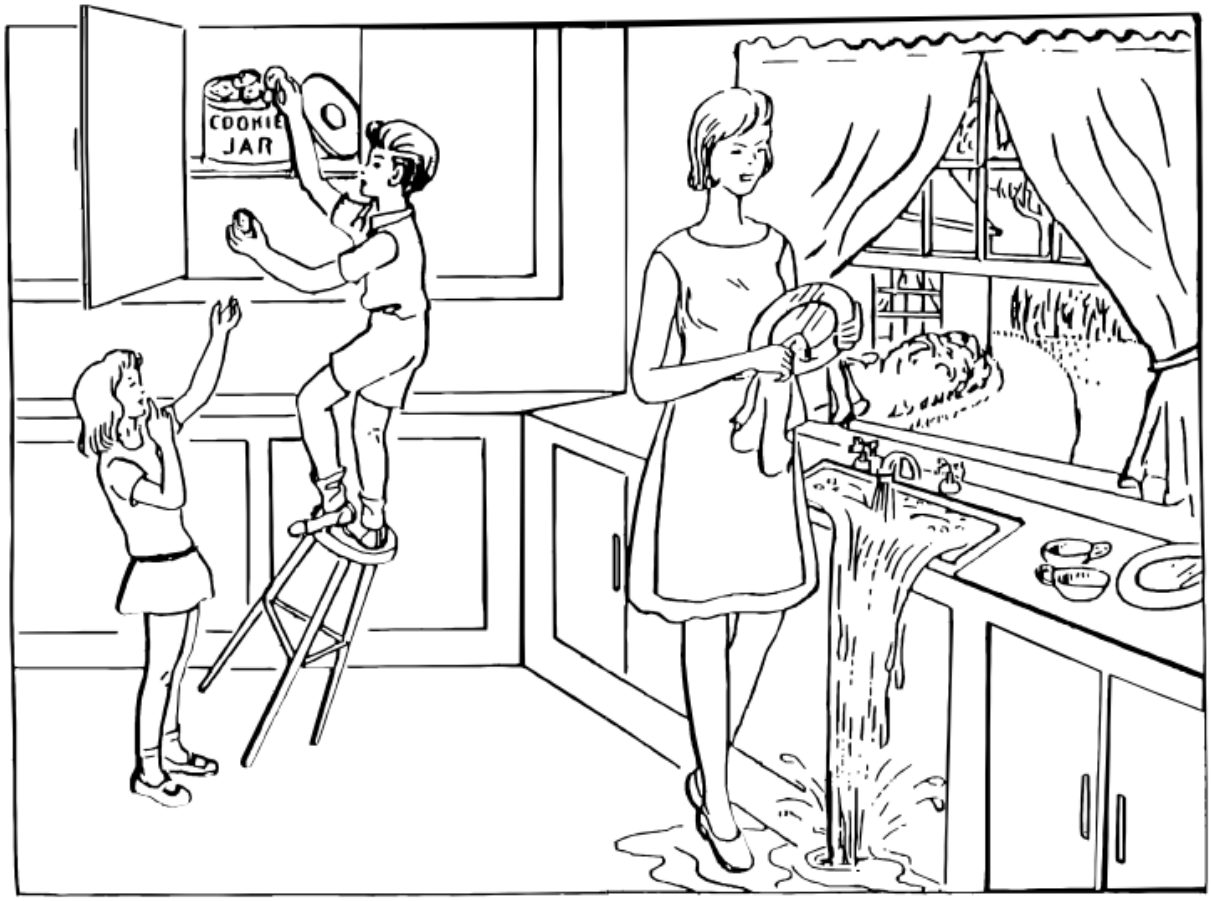
Pt. Date of Birth ___ ___/___ ___/___ ___

Hospital _____(___ ___-___ ___)

Date of Exam ___ ___/___ ___/___ ___

Interval: [ ] Baseline [ ] 2 hours post treatment [ ] 24 hours post onset of symptoms ±20 minutes [ ] 7-10 days
[ ] 3 months [ ] Other _____(___ ___)

7. Limb Ataxia: This item is aimed at finding evidence of a unilateral cerebellar lesion. Test with eyes open. In case of visual defect, ensure testing is done in intact visual field. The finger-nose-finger and heel-shin tests are performed on both sides, and ataxia is scored only if present out of proportion to weakness. Ataxia is absent in the patient who cannot understand or is paralyzed. Only in the case of amputation or joint fusion, the examiner should record the score as untestable (UN), and clearly write the explanation for this choice. In case of blindness, test by having the patient touch nose from extended arm position.	0 = **Absent.** 1 = **Present in one limb.** 2 = **Present in two limbs.** UN = **Amputation** or joint fusion, explain: _____	_____
8. Sensory: Sensation or grimace to pinprick when tested, or withdrawal from noxious stimulus in the obtunded or aphasic patient. Only sensory loss attributed to stroke is scored as abnormal and the examiner should test as many body areas (arms [not hands], legs, trunk, face) as needed to accurately check for hemisensory loss. A score of 2, "severe or total sensory loss," should only be given when a severe or total loss of sensation can be clearly demonstrated. Stuporous and aphasic patients will, therefore, probably score 1 or 0. The patient with brainstem stroke who has bilateral loss of sensation is scored 2. If the patient does not respond and is quadriplegic, score 2. Patients in a coma (item 1a=3) are automatically given a 2 on this item.	0 = **Normal;** no sensory loss. 1 = **Mild-to-moderate sensory loss;** patient feels pinprick is less sharp or is dull on the affected side; or there is a loss of superficial pain with pinprick, but patient is aware of being touched. 2 = **Severe to total sensory loss;** patient is not aware of being touched in the face, arm, and leg.	_____
9. Best Language: A great deal of information about comprehension will be obtained during the preceding sections of the examination. For this scale item, the patient is asked to describe what is happening in the attached picture, to name the items on the attached naming sheet and to read from the attached list of sentences. Comprehension is judged from responses here, as well as to all of the commands in the preceding general neurological exam. If visual loss interferes with the tests, ask the patient to identify objects placed in the hand, repeat, and produce speech. The intubated patient should be asked to write. The patient in a coma (item 1a=3) will automatically score 3 on this item. The examiner must choose a score for the patient with stupor or limited cooperation, but a score of 3 should be used only if the patient is mute and follows no one-step commands.	0 = **No aphasia;** normal. 1 = **Mild-to-moderate aphasia;** some obvious loss of fluency or facility of comprehension, without significant limitation on ideas expressed or form of expression. Reduction of speech and/or comprehension, however, makes conversation about provided materials difficult or impossible. For example, in conversation about provided materials, examiner can identify picture or naming card content from patient's response. 2 = **Severe aphasia;** all communication is through fragmentary expression; great need for inference, questioning, and guessing by the listener. Range of information that can be exchanged is limited; listener carries burden of communication. Examiner cannot identify materials provided from patient response. 3 = **Mute, global aphasia;** no usable speech or auditory comprehension.	_____
10. Dysarthria: If patient is thought to be normal, an adequate sample of speech must be obtained by asking patient to read or repeat words from the attached list. If the patient has severe aphasia, the clarity of articulation of spontaneous speech can be rated. Only if the patient is intubated or has other physical barriers to producing speech, the examiner should record the score as untestable (UN), and clearly write an explanation for this choice. Do not tell the patient why he or she is being tested.	0 = **Normal.** 1 = **Mild-to-moderate dysarthria;** patient slurs at least some words and, at worst, can be understood with some difficulty. 2 = **Severe dysarthria;** patient's speech is so slurred as to be unintelligible in the absence of or out of proportion to any dysphasia, or is mute/anarthric. UN = **Intubated** or other physical barrier, explain:_____	_____
11. Extinction and Inattention (formerly Neglect): Sufficient information to identify neglect may be obtained during the prior testing. If the patient has a severe visual loss preventing visual double simultaneous stimulation, and the cutaneous stimuli are normal, the score is normal. If the patient has aphasia but does appear to attend to both sides, the score is normal. The presence of visual spatial neglect or anosagnosia may also be taken as evidence of abnormality. Since the abnormality is scored only if present, the item is never untestable.	0 = **No abnormality.** 1 = **Visual, tactile, auditory, spatial, or personal inattention** or extinction to bilateral simultaneous stimulation in one of the sensory modalities. 2 = **Profound hemi-inattention or extinction to more than one modality;** does not recognize own hand or orients to only one side of space.	_____



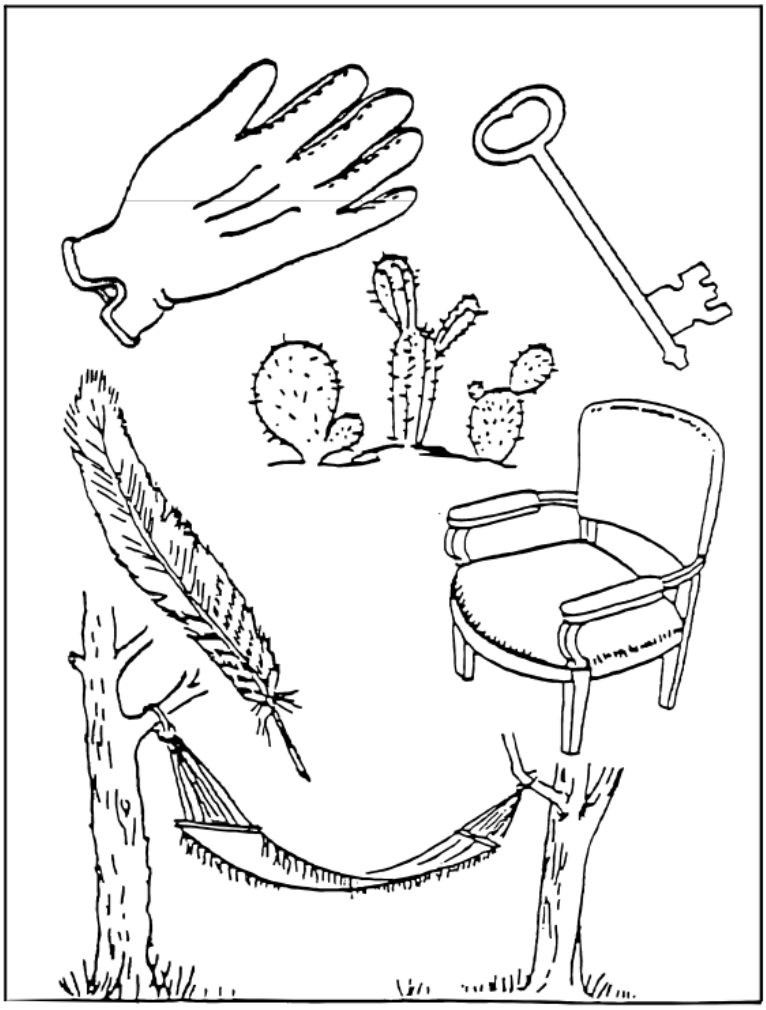
You know how.

Down to earth.

I got home from work.

Near the table in the dining room.

They heard him speak on the radio last night.



MAMA

TIP – TOP

FIFTY – FIFTY

THANKS

HUCKLEBERRY

BASEBALL PLAYER

ABCD^2 Algorithm for Risk of Stroke Following TIA

ABCD² algorithm (1) predicts a patient's very early risk of stroke following a TIA.

The score is calculated according to 5 important clinical features:

Symbol	Clinical feature	Criterion	Point
A	Age	>= 60	1
B	Blood pressure	>= 140/90 mmHg	1
C	Clinical features of the TIA	Unilateral weakness	2
		Speech disturbance without weakness	1
D1	Duration of symptoms	>= 60 min	2
		10-59 min	1
		<10 min	0
D2	Diabetes	Diagnosed with diabetes?	1

The corresponding 2 day risks for a subsequent stroke are:

ABCD2 score	Risk of stroke at 2 days
0-3	1%
4-5	4%
6-7	8%

Reference: Johnston, S., Rothwell, P., Nguyen-Huynh, M., Giles, M., Elkins, J., Bernstein, A., & Sidney, S. (2007). Validation and refinement of scores to predict very early stroke risk after transient ischaemic attack. *Lancet, 369*, 283-292.

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA

Effect of seated and supine exercise on cognition in healthy, older adults.

INVITATION LETTER TO HEALTHY CONTROLS

To whom it may concern,

My name is Rebecca Grigg and I am currently studying towards my Masters of Health Science majoring in sport and exercise. My supervisors, Dr James Faulkner (School of Sport and Exercise) and Dr Danielle Lambrick (Institute of Food, Nutrition and Human Health), who are both lecturers at Massey University, have recently gained ethical approval to conduct an exciting exercise study involving healthy men and women between the ages of 50 and 70 years. The study intends to assess the effect of maximal and submaximal exercise on cognitive function. Research has shown that exercise increases the amount of oxygen that goes to the front of the brain. In this study, we are interested in identifying whether this increase in the amount of oxygen going to the brain improves cognition. If cognition is improved in this study, we intend to conduct future research which will assess the effect of exercise in individuals who experience neurological and cognitive impairments (i.e., stroke patients).

In this study, men and women between the ages of 50 and 70 years will be asked to attend the Exercise Physiology Research Laboratory at Massey University (Wellington campus) on six separate occasions, over a three week period. Written informed consent will be obtained from participants prior to participation in the study. During the first visit a health screening questionnaire and coronary artery disease risk stratification assessment will be assessed. Here, blood pressure, smoking status, blood glucose and total cholesterol (as determined by a finger prick capillary sample) will be obtained. Once we have identified that there are no concerns with a participants health status, individuals will be asked to cycle for 10 minutes at two low exercise intensities on a seated cycle ergometer. Participants will also be familiarized with a short cognitive function test known as the 'Stroop'. Following a 72 hour recovery, participants will be asked to attend the laboratory for a second occasion whereby they will be familiarized with a recumbent exercise bike. Participants will again perform 10 minutes of low-intensity exercise during this visit and will be re-familiarized with the Stroop task. Thereafter, participants will complete two maximal exercise tests and two submaximal exercise tests, with a minimum 72 hour recovery period between tests. The two maximal tests are continuous and incremental in nature, commencing at a low intensity and progressively increasing until volitional exhaustion. These tests usually take between 12 and 15 minutes to complete. Following a 15 minute recovery, participants will cycle at 105 % of the highest power output reported from the initial test to make sure that the highest values (i.e., heart rate) for each participant are identified. These tests will be performed on a seated and recumbent exercise bike. During the two remaining sessions, participants will be asked to perform a submaximal exercise test that will be of a moderate intensity (on a seated and recumbent exercise bike). This exercise intensity will be determined by physiological criteria achieved from the maximal exercise tests. These submaximal tests will take 30 minutes to

complete. Participants will be asked to wear some testing equipment, including; i) a facemask to measure breathing rate, ii) an electrode will placed on the forehead to measure how much oxygen is going to the brain, and iii) a heart rate monitor.

Participants will be in the lab for 60 minutes for both maximal exercise tests, and 90 minutes for both submaximal exercise tests. The initial familiarization session will take approximately 30 minutes, while the second familiarization session will take approximately 15 minutes. The total time requirement to participate in this study will be approximately 5 hours 45 minutes.

If interested in taking part, please read the attached information sheet. If you wish to talk to me or either of my supervisors in person, please do not hesitate to contact us on the details provided below.

Best wishes,

Rebecca Grigg
Post Graduate student
Master of Health Science (Sport & Exercise)
Massey University
Email: R.M.Grigg@massey.ac.nz

Supervisory team:

Dr James Faulkner — Phone: (04) 801 5799 ext 60421
(Lecturer in Exercise Prescription) — Email: J.Faulkner@massey.ac.nz

Dr Danielle Lambrick — Phone: (04) 801 5799 ext 62375
(Lecturer in Health and Life Sciences) — Email: D.Lambrick@massey.ac.nz

"This project has been reviewed and approved by the Massey University Human Ethics Committee: Southern A, Application 13/81. If you have any concerns about the conduct of this research, please contact Dr Brian Finch, Chair, Massey University Human Ethics Committee: Southern A, telephone 06 350 5799 x 84459, email humanethicsoutha@massey.ac.nz."

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA

Effect of seated and supine exercise on cognition in healthy, older adults.

INFORMATION SHEET FOR HEALTHY CONTROLS

Introduction
You are being invited to take part in a research study by Drs James Faulkner and Danielle Lambrick; lecturers from the School of Sport and Exercise, and the Institute of Food, Nutrition and Human Health, respectively, at Massey University (Wellington). Before you decide if you would like to take part, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. If there is anything that is not clear to you or if you would like more information, please do not hesitate to contact me on the details provided below. Take time to decide whether or not you wish to take part. If you decide not to take part, it is not a problem and we thank you for considering our request. If you do decide to take part, you will be asked to sign a consent form. If you decide to take part, you are still free to withdraw at any time without prejudice or without giving a reason. Participants can even stop participating in the project during an exercise test.

What is the purpose of the study?
The study intends to assess the effect of submaximal, moderate-intensity exercise on cognitive function in men and women between the age of 50 and 70 years. Research has shown that exercise increases oxygenation to the front of the brain. In this study we are interested in identifying whether an increase in oxygenation to the brain when taking part in exercise improves cognition. Based on the findings of this study, we would like to conduct research into the effects of exercise on cognition in individuals who have experienced neurological and cognitive impairments (i.e., stroke patients).

How are participants recruited?
Participants will be recruited from Massey University (Wellington campus) and the BPM fitness studio. An invitation letter and information sheet will be sent to all members of staff on the Massey University Wellington campus. With regards to BPM, the manager of the gym will be informed of the proposed study and will be asked to provide the invitation letter and information sheet to its members. The letter will provide details of the study and what is being asked in terms of participation. Those interested in taking part can contact Dr James Faulkner or Dr Danielle Lambrick by email or telephone. Participant recruitment will be stopped once 15 individuals have been recruited to the study.

Are there any inclusion or exclusion criteria?
INCLUSION

- Healthy, men and women between the ages of 50 and 70 years.
- No symptoms of illness or pre-existing injuries
- Up to fifteen subjects will be recruited

A health history questionnaire and coronary artery disease risk stratification measures, including the assessment of blood glucose, total cholesterol, blood pressure and smoking

status will be assessed prior to the initial exercise test, as recommended by the American College of Sports Medicine (ACSM, 2013). Information obtained from these assessments may determine your suitability to take part in the exercise portion to this study.

EXCLUSION

- Men and women under 50 years of age, or over 70 years of age
- Those considered 'high-risk' of cardiovascular disease as determined by the coronary artery disease risk stratification assessment, as determined by the ACSM (2013).
- Those who suffer from chest pains or heart trouble
- Personal history of diabetes, hypertension or vascular disease
- Muscular problems that may be aggravated by exercise
- Muscle injury/fracture in the last 3 months
- Individuals who are blind, or colour blind
- Individuals who have allergies to adhesives or other skin conditions which may be inflamed when wearing adhesive pads on the forehead.

Participants will experience physical discomfort in each of the exercise tests. However, this feeling should be no different to the feelings usually encountered by athletes during training and competition.

What will I be asked to do if I agree to take part?

Participants who agree to take part in this study will be asked to visit the Sport and Exercise Science research laboratory, Massey University (Wellington), on six separate occasions, over a two week period. During the first visit a health screening questionnaire and coronary artery disease risk stratification assessment will be assessed. Here, your blood pressure, smoking status, blood glucose and total cholesterol (as determined by a finger prick capillary sample) will be obtained. Once we have identified that there are no concerns with your health status, you will then be asked to cycle for 10 minutes at two low exercise intensities on a seated cycle ergometer. You will also be asked to complete a short cognitive test known as the Stroop test (see page 3 for further information). Following a 72 hour recovery, you will be asked to attend the lab for a second occasion whereby you will be familiarized with the recumbent cycle ergometer, and will again complete a Stroop test. You will again perform 10 minutes of low-intensity exercise during this visit. Thereafter, participants will complete two maximal exercise tests and two submaximal exercise tests, with a minimum 72 hour recovery period between tests. All exercise tests will take place in the morning (between 7 and 10 am) in a fasted state. As such, participants will be asked not to consume food the morning of any of the exercise tests. The two maximal tests are continuous and incremental in nature, commencing at a low intensity and progressively increasing until you report volitional exhaustion (i.e., you have exercised to your maximum!). These tests usually take between 12 and 15 minutes. Following a 15 minute recovery, you will cycle at 105 % of your peak power output to verify your maximal oxygen consumption from the initial, incremental exercise test. These tests will be performed on a seated and recumbent ergometer. During the two remaining sessions, you will be asked to perform a submaximal exercise test that will be of a moderate intensity (on a seated and recumbent cycle ergometer). This exercise intensity will be determined by physiological criteria achieved from your maximal exercise tests. These submaximal tests will take 30 minutes.

Prior to-, immediately after and 30-minutes following the two submaximal tests you will be asked to complete a cognitive test known as the 'Stroop'. This task is designed to

assess your 'executive function (i.e., mental processes required to select and organise goal-directed actions). During this test you will be shown words of colours (blue, yellow, green, red) in the middle of a computer screen. These words will appear in different colours, sometimes matching the word (e.g., the word blue, written in blue), and sometimes not matching the word (e.g., the word blue, written in yellow; see picture to the left). There are four buttons with the colour words on them below the presented colour word. For the first part of the Stroop test, you will be asked to click the right button, as fast as possible, that matches the colour of the word, ignoring the word itself. In the second part, you will be asked to click on the name of the colour word presented, ignoring the colour itself. As soon as you have clicked a button, another word appears.

You will also be asked to wear three pieces of equipment throughout testing session. You will wear a heart rate monitor which is worn on a strap around your chest (see picture below). To measure your oxygen consumption and carbon dioxide production prior-to, during and after exercise, you will be asked to wear a face mask. When you wear the face mask you will be able to breathe comfortably and talk easily, even whilst exercising (picture below).

The third piece of equipment will be a small monitor that will be attached to your forehead (see picture to the left). This monitor is about the size of a 9V square battery but is very thin and flexible, and it measures how much oxygen is being used in the brain. You will also be asked to tell us how hard the exercise feels to you during each test by using a subjective ratings of perceived exertion scale. During the entire study, at least two first aid qualified researchers will be present and a first aid kit will be available at all times. Finally, prior-to the two submaximal exercise tests, a cannula will be inserted into your antecubital vein. This will allow a blood sample (6 ml) be obtained before, immediately following and 30-minutes after both sub-maximal exercise bouts. On completion of all exercise testing sessions, participants will be provided a small snack (fruit bar) to help replenish energy stores.

Participants will be in the lab for 60 minutes for both maximal exercise tests, and 90 minutes for both submaximal exercise tests. The initial familiarization session will take approximately 30 minutes, while the second familiarization session will take approximately 15 minutes. The total time requirement to participate in this study will be approximately 5 hours 45 minutes.

What are possible disadvantages and risks of taking part?

1) Physiological exhaustion at the completion of the first two exercise tests

2) Delayed onset of muscle soreness (DOMS) as a consequence of the exercise tests
3) Minor discomfort at the time of the finger prick capillary sample and insertion of the cannula
4) There is a small risk of death associated with undertaking physical activity (between 1 death in 10,000 athletes and 1 death in 200,000 athletes; Noakes, 1998). Dr Faulkner and Dr Lambrick have been first aid trained for 5+ years, most recently completing a Comprehensive Red Cross first aid course in March 2013. Dr Faulkner and Dr Lambrick are also trained with the use of a defibrillator. A defibrillator will be located in the physiology laboratory throughout each exercise test.

What are the possible benefits of taking part?

The results from your cardiovascular risk stratification assessment and exercise tests will be analysed. Dr Faulkner will provide you with a written copy of your results and will verbally explain what the results mean to you. The information discussed will focus on your specific physiological response to exercise. Some training recommendations may also be available to you based upon your lab testing results. As individuals will be participating in physical exertion at least four times, this will be beneficial for health and fitness. As a coronary artery disease risk stratification assessment is also being undertaken prior to exercise, your risk of cardiovascular disease will also be identified and discussed with you.

What if something goes wrong?

Compensation of Injury.

If physical injury results from your participation in this study, you should visit a treatment provider to make a claim to ACC as soon as possible. ACC cover and entitlements are not automatic and your claim will be assessed by ACC in accordance with the Accident Compensation Act 2001. If your claim is accepted, ACC must inform you of your entitlements, and must help you access those entitlements. Entitlements may include, but not be limited to, treatment costs, travel costs for rehabilitation, loss of earnings and/or lump sum for permanent impairment. Compensation for mental trauma may also be included, but only if this is incurred as a result of physical injury.

If your ACC claim is not accepted you should immediately contact the researcher. The researcher will initiate processes to ensure you receive compensation equivalent to that which you would have been entitled had ACC accepted your claim.

Data Management

All information which is collected about you during the course of the research study will be kept strictly confidential. You will be identified with an alpha-numeric code on all record sheets. The data will be analysed as group means and individual participant's identities will not be disclosed on any documentation (other than signed consent form). The data will be kept for 10 years by Dr. Faulkner to allow the investigators to return to the source of the data if/when needed. All physical documents will be shredded after the due date, and all electronic data will be wiped from the hard drive.

Your Rights

You are under no obligation to accept this invitation. If you decide to participate, you have the right to:

- Decline to answer any particular question
- Withdraw from the study at the time of physical testing
- Ask any questions about the study at any time during participation
- Provide information on the understanding that your name will not be used unless you give permission to the researcher
- Be given access to a summary of the project findings when it is concluded.

What will happen to the results of the research study?

A summary of the research findings will be available electronically (or hard copy where necessary) to all participants. Your results from the coronary artery disease risk stratification assessment and exercise tests will be analysed and Dr Faulkner will discuss these with you. The research findings will be submitted to a peer reviewed scientific journal for publication, and it is expected that the findings will also be presented at a national or international conference.

Who is organizing and funding the research?

The research will be organized and conducted by Dr. James Faulkner from the School of Sport and Exercise and Dr. Danielle Lambrick from the Institute of Food, Nutrition and Human Health. Rebecca Grigg is a post graduate student studying towards her Master of Health Science (Sport and Exercise) who will also be involved in this research.

Who may I contact for further information?

If you would like more information about the research before you decide whether or not to you would be willing to take part, please contact:

Dr. James Faulkner
School of Sport and Exercise
Massey University
Private Bag 756
Wellington
6140

Email: J.Faulkner@massey.ac.nz
Telephone: 04 801 5799 ext 62104

Dr. Danielle Lambrick
IFNHH
Massey University
Private Bag 756
Wellington
6140

Email: D.Lambrick@massey.ac.nz
Telephone: 04 801 5799 ext 62375

Rebecca Grigg
Email: R.M.Grigg@massey.ac.nz

Thank you for your interest in this research study.

Committee Approval Statement:

This project has been reviewed and approved by the Massey University Human Ethics Committee: Southern A, Application 13/81. If you have any concerns about the conduct of this research, please contact Dr Brian Finch, Chair, Massey University Human Ethics Committee: Southern A, telephone 06 350 5799 x 84459, email humanethicsoutha@massey.ac.nz.

Extract From Information Sheet for TIA Patients

MASSEY UNIVERSITY
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Study title:	**Effect of early exercise engagement on cardiovascular and cerebrovascular health in stroke and high risk TIA patients.**		
Locality:	**Wellington Region**	Ethics committee ref.:	**13/CEN/72**
Lead investigator:	**Dr James Faulkner**	Contact phone number:	**(04) 801 5799 x 62104**

Additional study option: Effect of exercise on cognition in stroke and TIA patients.

If you have been randomized to the exercise program you will be invited to take part in a separate research question. The purpose of this part of the study is to assess the effect of an acute bout of exercise on cognitive function. If interested in taking part, you will be asked to complete an additional informed consent form **(Consent Form III: Exercise and Cognition).** For this study question, instead of starting your exercise program in the Massey University gym as stated earlier in this information sheet, you will be asked to visit the Massey University Exercise Physiology Laboratory, twice a week for the first two weeks of your 12 week exercise program. You will take part in four aerobic exercise sessions, two of which will be performed on an upright stationary bike, and two on a recumbent cycle ergometer. For both modes of exercise (upright and recumbent), the initial exercise test will be a continuous and incremental maximal exercise test similar to your baseline fitness assessment. During the remaining two tests, you will be asked to cycle at a moderate exercise intensity for 30 minutes. Before and after each of these exercise tests, your cognitive function (i.e., mental processes required to select and organise goal-directed actions) will be assessed using the Stroop test. This test will involve you being presented with several colour words (blue, yellow, green, red) on a computer screen. These words will appear in different colours. You will be asked to sometimes match the word (e.g., the word blue, written in blue), and sometimes not matching the word (e.g., the word blue, written in red). The number of correct ‘matches’ and the time to complete the test will be recorded.

Brain-derived neurotrophic factor (BDNF), a brain protein, will also be assessed before and after each bout of exercise via a venous blood sample. BDNF has been linked with brain volume and cognitive function in healthy older adults, and may provide an insight into the mechanism involved in exercise-induced changes in cognition.

Similar physiological markers as the baseline fitness assessment (ECG, heart rate, NIRS, respiratory markers) will be monitored throughout these exercise sessions.

If you decide that you do not want to take part in this additional study question that is absolutely fine. You will commence your exercise program in the Massey University recreation centre as previously outlined.

Note: The section above has been extracted (p. 6) from the full TIA Participant Information sheet as it provides the most relevant information for this present study.

Informed Consent for Healthy Controls

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA

Effect of seated and supine exercise on cognition in healthy, older adults.

Participant Consent Form – Individual

I have read the Information Sheet and have had the details of the study explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.

I wish/do not wish to have data placed in an official archive.

I request any remaining blood sample be destroyed at the end of the study:

- By Standard Disposal **YES / NO**
- With appropriate Karakia **YES / NO**

I agree to participate in this study under the conditions set out in the Information Sheet.

Signature: _____ **Date:** _____

Full Name – printed: _____

Informed Consent for TIA Patients

Consent Form III: Exercise and Cognition

Study title:	**Effect of early exercise engagement on cardiovascular and cerebrovascular health in stroke patients**		
Locality:	**Massey University (Wellington)** **Otago Medical School (Wellington)** **CCDHB Wellington Regional Hospital**	Ethics committee ref.:	**13/CEN/72**
Lead investigator:	**Dr James Faulkner**	Contact phone number:	**0(4) 801 5799 ext 62104**

Declaration by participant:

I have read, or have had read to me in my first language, and I understand the Participant Information Sheet. I have had the opportunity to ask questions and I am satisfied with the answers I have received.

I agree to take part in four laboratory-based exercise tests during the first two weeks of the 12 week exercise program

I will provide a blood sample before and after each exercise bout in the knowledge that they will be used to assess brain-derived neurotrophic factor (BDNF); a brain protein.

I agree that all blood samples taken from me will be stored for a period no longer than 10 years

I request any remaining blood sample be destroyed at the end of the study:

- By Standard Disposal **YES / NO**
- With appropriate Karakia **YES / NO**

I freely agree to participate in this part of the study.

I have been given a copy of the Participant Information Sheet and Consent Form to keep.

Participant's name: _____

Signature: _____ Date: _____

Declaration by member of research team:

I have given a verbal explanation of the research project to the participant, and have answered the participant's questions about it.

I believe that the participant understands the study and has given informed consent to participate.

Researcher's name: _____

Signature: _____ Date: _____

Health History Questionnaire

GENDER: M / F

DESCENT: European, Maori, Pacific Islander, Asian, Indian, Other TODAY'S DATE _____

NAME _____ AGE _____ DATE OF BIRTH _____

ADDRESS _____
Street City State Zip

TELEPHONE: HOME/CELL _____/ _____ E-MAIL ADDRESS _____

OCCUPATION/EMPLOYER _____/ _____ BUSINESS PHONE _____

MARITAL STATUS: (check one) SINGLE ☐ MARRIED ☐ DIVORCED ☐ WIDOWED ☐

PERSONAL PHYSICIAN _____ PHONE # _____

ADDRESS _____

Reason for last doctor visit? _____ Date of last physical exam: _____

Have you ever had any other exercise stress test? YES ☐ NO ☐ DATE & LOCATION OF TEST: _____

Have you ever had any cardiovascular tests? YES ☐ NO ☐ DATE & LOCATION: _____

Person to contact in case of an emergency _____ Phone _____ (relationship) _____

Please provide responses (YES or NO) to the following concerning family history, your own history, and any symptoms you have had:

FAMILY HISTORY

Have any immediate family members had a:

	YES	NO
heart attack	o	o
heart surgery	o	o
coronary stent	o	o
cardiac catheterization	o	o
congenital heart defect	o	o
stroke	o	o

Other chronic disease: _____

PERSONAL HISTORY

Have you ever had:

	YES	NO
High blood pressure	o	o
High cholesterol	o	o
Diabetes	o	o
Any heart problems	o	o
Disease of arteries	o	o
Thyroid disease	o	o
Lung disease	o	o
Asthma	o	o
Cancer	o	o
Kidney disease	o	o
Hepatitis	o	o

Other: _____

SYMPTOMS

Have you ever had:

	YES	NO
Chest pain	o	o
Shortness of breath	o	o
Heart palpitations	o	o
Skipped heartbeats	o	o
Heart murmur	o	o
Intermittent leg pain	o	o
Dizziness or fainting	o	o
Fatigue -- usual activities	o	o
Snoring	o	o
Back pain	o	o
Orthopedic problems	o	o

Other: _____

STAFF COMMENTS: _____

Have you ever had your cholesterol measured? Yes ☐ No ☐ If yes, value _____ Where: _____

Are you taking any prescription (include birth control pills) or nonprescription medications? Yes ☐ No ☐

For each of your current medications, provide the following information:

MEDICATION Dosage–times/day Time taken Years on medication Reason for taking

HOSPITALIZATIONS: Please list recent hospitalizations (Women: do not list normal pregnancies)

Year Location Reason

_____

_____

_____

Any other medical problems/concerns not already identified? Yes ☐ No ☐ If so, please list: _____

_____

_____

LIFESTYLE HABITS

Do you ever have an uncomfortable shortness of breath during exercise or when doing activities?
Yes ☐ No ☐

Do you ever have chest discomfort during exercise? Yes ☐ No ☐
If so, does it go away with rest? Yes ☐ No ☐

_____

Do you currently smoke? Yes ☐ No ☐ If so, what? Cigarettes ☐ Cigars ☐ Pipe ☐
How long have you smoked? _____ years
How much per day: <½ pack ☐ ½ to 1 pack ☐ 1 to 1½ packs ☐ 1½ to 2 packs ☐ >2 packs ☐
Have you ever quit smoking? Yes ☐ No ☐ When? _____
How many years and how much did you smoke? _____
Do you drink any alcoholic beverages? Yes ☐ No ☐ If yes, how much in 1 week? (indicate below)
Beer _____ (cans) Wine _____ (glasses) Hard liquor _____ (drinks)
Do you drink any caffeinated beverages? Yes ☐ No ☐ If yes, how much in 1 week? (indicate below)
Coffee _____ (cups) Tea _____ (glasses) Soft drinks _____ (cans)
Are you currently following a weight reduction diet plan? Yes ☐ No ☐
If so, how long have you been dieting? _____ months
Is the plan prescribed by your doctor? Yes ☐ No ☐
Have you used weight reduction diets in the past? Yes ☐ No ☐ If yes, how often and what type? _____

_____

ACTIVITY LEVEL EVALUATION

What is your occupational activity level? Sedentary ☐ Light ☐ Moderate ☐ Heavy ☐
Do you currently engage in vigorous physical activity on a regular basis? Yes ☐ No ☐
If so, what type(s)? _____ How many days per week? _____
How much time per day? <15 min ☐ 15–30 min ☐ 31–60 min ☐ >60 min ☐
How long have you engaged in this type of activity? <3 months ☐ 3–12 months ☐ >1 year ☐

_____

Do you engage in any recreational or leisure-time physical activities on a regular basis? Yes ☐ No ☐
If so, what activities? _____
On average: How often?_____ times/week; for how long? _____ time/session
How long have you engaged in this type of activity? <3 months 3–12 months >1 year

_____

Your fitness goals and objectives are: _____

_____

STAFF COMMENTS: _____

_____

_____

Health Screening Questionnaire

Name: _____

Address: _____

Phone: _____

Age: _____

Please read the following questions carefully. If you have any difficulty, please advise the exercise specialist who is conducting the exercise test.

Please answer all of the following questions by ticking only one box for each question:

This questionnaire has been designed to identify the small number of persons (15-69 years of age) for whom physical activity might be inappropriate. The questions are based upon the Physical Activity Readiness Questionnaire (PAR-Q), originally devised by the British Columbia Dept of Health (Canada), as revised by [1]Thomas *et al.* (1992) and [2]Cardinal *et al.* (1996), and with added requirements of the Massey University Human Ethics Committee. The information provided by you on this form will be treated with the strictest confidentiality.

Qu 1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?

Yes ☐ No ☐

Qu 2. Do you feel a pain in your chest when you do physical activity?

Yes ☐ No ☐

Qu 3. In the past month have you had chest pain when you were not doing physical activity?

Yes ☐ No ☐

Qu 4. Do you lose your balance because of dizziness or do you ever lose consciousness?

Yes ☐ No ☐

Qu 5. Are you currently using prescription medication?

Yes ☐ No ☐

Qu 6. Do you have a bone or joint problem that could be made worse by vigorous exercise, particular in the lower back and/or legs?

Yes ☐ No ☐

Qu 7. Do you have any pre-existing muscular problems or injuries that may be aggravated by repetitive, vigorous physical activity?

Yes ☐ No ☐

Qu 8. Do you know of any other reason why you should not do physical activity?

Yes ☐ No ☐

Qu 9. Have any immediate family members had heart problems prior to the age of 55?

Yes ☐ No ☐

Qu 10. Have you been hospitalised recently?

Yes ☐ No ☐

Qu 11. Are you diabetic?

Yes ☐ No ☐

Qu 12. Do you currently or have you previously had renal and/or hepatic disease?

Yes ☐ No ☐

Qu 13. Do you have any infectious disease that may be transmitted in blood?

Yes ☐ No ☐

Qu 14 Do you have any skin allergies or sensitivities to adhesives (i.e. plasters)?

Yes ☐ No ☐

You should be aware that even amongst healthy persons who undertake regular physical activity there is a risk of sudden death during exercise. Though extremely rare, such cases can occur in people with an undiagnosed heart condition. If you have any reason to suspect that you may have a heart condition that will put you at risk during exercise, you should seek advice from a medical practitioner before undertaking an exercise test.

I have read, understood and completed this questionnaire.

Signature: _____ Date: _____

References

1. Thomas S, Reading J and Shephard RJ. Revision of the Physical Activity Readiness Questionnaire (PAR-Q). *Can J Sport Sci* 17(4): 338-345.
2. Cardinal BJ, Esters J and Cardinal MK. Evaluation of the revised physical activity readiness questionnaire in older adults. *Med Sci Sports Exerc* 28(4): 468-472

Ethics Approval Letter

Health and Disability Ethics Committees

Health and Disability Ethics Committees
1 The Terrace
PO Box 5013
Wellington
6011

0800 4 ETHICS
hdecs@moh.govt.nz

20 May 2013

Dr James Faulkner
Massey University, Block 4
63 Wallace St
Mt Cook
Wellington 6021

Dear Dr Faulkner

Re:	**Ethics ref:**	**13/CEN/72**
	Study title:	Effect of early exercise engagement on cardiovascular and cerebrovascular health in stroke and high risk TIA patients

I hereby confirm receipt of this application for HDEC review, which was submitted on 16 May 2013.

Arrangements for HDEC review

Your application has been assigned for HDEC review by the HDEC-Full Review pathway.

HDEC:	Central Health and Disability Ethics Committee
Time:	4.30-5.00pm
Meeting date:	28 May 2013
Meeting venue:	Deloitte House, MEDSAFE, Level 6, 10 Brandon Street, Wellington
Teleconferencing:	Dial 083033 then 457013

We encourage you to attend this meeting in person or by teleconference, or to have a co-investigator attend in your place. Your attendance may facilitate the HDEC review process by allowing some issues to be discussed and resolved at the meeting itself, rather than in correspondence after it. Please contact us as soon as possible to confirm whether you or a co-investigator can attend.

No amendments to be made before HDEC approval

No amendments can be made to your application before it is approved, except where requested by the HDEC as a condition of approval. If you think you may need to amend your application during this time, we advise you to withdraw and re-submit it at a later date.

Please don't hesitate to contact us for further information.

Yours sincerely,

Awhina Rangiwai
Administrator
Health and Disability Ethics Committees
hdecs@moh.govt.nz

Encl: appendix A: documents submitted
appendix B: statement of compliance and list of members

Ratings of Perceived Exertion Scale (RPE)

6 No exertion at all

7 Extremely light

8

9 Very light

10

11 Light

12

13 Somewhat hard

14

15 Hard (heavy)

16

17 Very hard

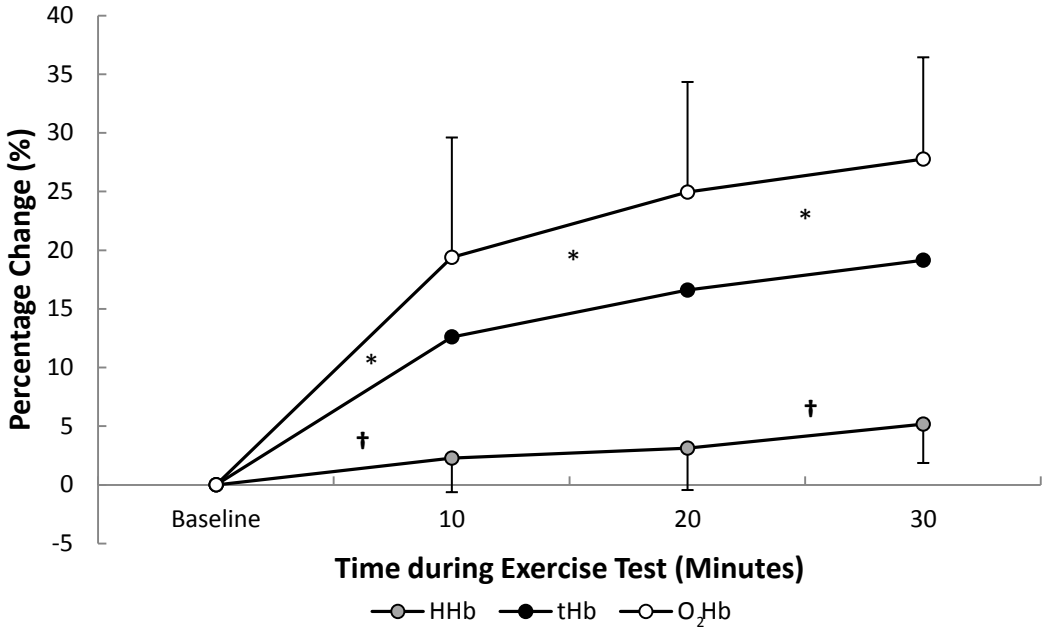
18

19 Extremely hard

20 Maximal exertion

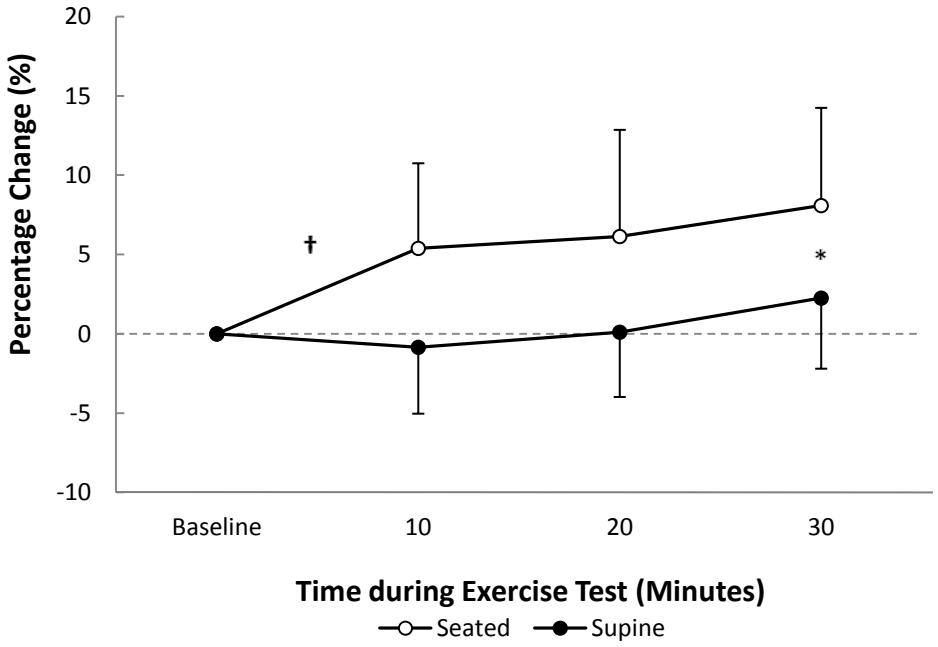
Borg RPE scale

NIRS and Physiological Variables during Exercise



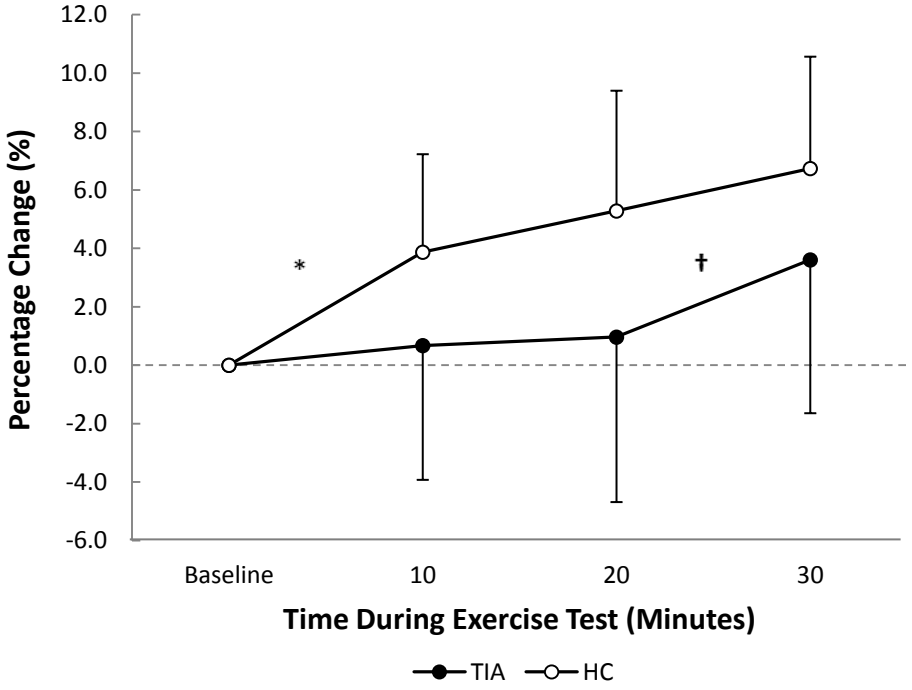
*Significant increase between each consecutive time point for O_2Hb and tHb (all $P < 0.001$); †Significant increase between Baseline and 10-minutes and 20- and 30-minutes of exercise for HHb ($P < 0.01$).

Figure M1. Percentage change in NIRS measures from Baseline and during exercise.



*Significant difference between the Seated and Supine exercise for HHb ($P < 0.001$). †Significant increase in HHb between Baseline and 10-minutes for Seated exercise ($P < 0.001$).

Figure M2. Percentage change in HHb from Baseline during the Seated and Supine exercise test.



*Significant increase in HHb between Baseline and 10-minutes of exercise for HC participants ($P < 0.01$).

†Significant increase in HHb between 20- and 30-minutes of exercise for TIA patients ($P < 0.01$).

Figure M3. Percentage change in HHb from Baseline during exercise for TIA and HC participants.

Table M1. Mean (±SD) of physiological variables recorded during the Seated and Supine exercise tests.

	10-min		20-min		30-min	
	Seated	**Supine**	**Seated**	**Seated**	**Seated**	**Supine**
$\dot{V}O_{2peak}$ ($L \cdot min^{-1}$)	22.2 ± 6.4	19.8 ± 4.5	23.3 ± 6.1	21.7 ± 4.5	24.2 ± 5.1	22.2 ± 4.6*º
$\dot{V}_E$ ($L \cdot min^{-1}$)	49.7 ± 15.7	45.7 ± 12.2	53.9 ± 15.8	49.9 ± 12.8	57.3 ± 14.1	51.0 ± 13.3
RER	0.9 ± 0.0	1.0 ± 0.1	0.9 ± 0.0	0.9 ± 0.0	0.9 ± 0.0	0.9 ± 0.0
HR ($b \cdot min^{-1}$)	120.9 ± 11.2	110.5 ± 12.3	128.3 ± 11.2	115.7 ± 12.3	133.6 ± 11.9	119.5 ± 12.2*º□
SBP (mmHg)	179.8 ± 18.8#	186.8 ± 20.2	182.0 ± 18.8	184.3 ± 22.6	181.1 ± 20.1	187.8 ± 19.8*
DBP (mmHg)	81.4 ± 8.1	82.6 ± 9.3	79.5 ± 8.3	81.9 ± 8.7†	79.7 ± 7.5	82.0 ± 8.4*
RPE	11.4 ± 1.2	12.8 ± 1.5	12.7 ± 1.0	13.7 ± 1.7	13.5 ± 1.7	14.5 ± 1.7

*Significant difference between the Seated and Supine exercise tests for $\dot{V}O_2$, HR, SBP and DBP ($P < 0.05$); #Significant increase in SBP between Baseline and 10-minutes of Seated and Supine exercise ($P < 0.001$); †Significant decrease in DBP between 10- and 20-minutes of exercise ($P < 0.01$); ºSignificant increase between each consecutive time point for $\dot{V}O_2$ and HR (Both $P < 0.001$); □Significant different rate of change for HR during the Seated and Supine exercise tests between each consecutive time point ($P < 0.001$).

$\dot{V}O_2$ = oxygen consumption; $\dot{V}_E$ = Minute ventilation; RER = Respiratory exchange ratio; HR = Heart Rate; SBP = Systolic blood pressure; DBP = Diastolic blood pressure; RPE = Ratings of perceived exertion.